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Proceedings of the 1981 Intermountain Nurserymen's Association meeting

R. F. Huber (Compiler)
Northern Forest Research Centre

NOR-X-241

87-01581/

PROCEEDINGS OF THE 1981 INTERMOUNTAIN NURSERYMEN'S ASSOCIATION MEETING

August 11-13, 1981, in Edmonton, Alberta

Compiled by

R.F. Huber

INFORMATION REPORT NOR-X-241

NORTHERN FOREST RESEARCH CENTRE
CANADIAN FORESTRY SERVICE
ENVIRONMENT CANADA
1982

©Minister of Supply and Services Canada 1982
Catalogue No. FO46-12/241E
ISBN 0-662-12078-7
ISSN 0704-7673

Northern Forest Research Centre
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Edmonton, Alberta, Canada
T6H 3S5

Huber, R.F. (Compiler). 1982. Proceedings of the 1981 Intermountain Nurserymen's Association meeting, held August 11-13, 1981, in Edmonton, Alberta. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-241.

ABSTRACT

The 1981 annual meeting was held to pass nursery information to nurserymen, nursery personnel, foresters, and researchers from western Canada and the western United States. Papers were presented on nursery and reforestation programs, cold hardiness, soil fertility, water quality and irrigation, equipment, monitoring, cone handling, and nursery accounting.

RESUME

La réunion annuelle de l'Intermountain Nurserymen's Association, tenue du 11 au 13 aout 1981, avait pour but de renseigner les pépinieristes, le personnel des pépinieres, les forestiers ainsi que les chercheurs de l'Ouest canadien et de l'ouest des Etats-Unis sur les pépinieres. On y a présenté des communications sur les pépinieres et les programmes de restauration forestiere, la résistance au froid, la fertilité des sols, la qualité de l'eau et l'irrigation, l'éequipement, les méthodes de controle, la manutention des cones et al comptabilité dans une pépiniere.

ACKNOWLEDGMENTS

Thanks and appreciation go to the speakers, who took the time to prepare and present their papers, and to Alberta Agriculture and the Alberta Forest Service for the excellent tours of their nursery facilities. The contributions of Grayco Harvesters, Spencer-Lemaire Industries Ltd, Hood Manufacturing Enterprises Ltd., Canadian Forestry Equipment Ltd., and International Reforestation Supplies, which helped make our social functions a success, are also gratefully acknowledged.

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REFORESTATION AT THE PINE RIDGE FOREST NURSERY

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Alberta Forest Service
Edmonton, Alberta

It gives me great pleasure to talk on Alberta's reforestation policy and success because I feel we are highly successful in this area, and I hope the data I am about to present will bear this out.

Alberta is unique in Canada, as it is the only province to legally require the reforestation of all cutover forest lands. The policy of total reforestation has been in place for 15 years, beginning with the introduction of the quota system of timber disposal in 1966. Even earlier, in 1956, the groundwork was laid for establishing a long-term policy of sustained yield of forest products with the negotiation of the first Forest Management Agreement with Northwest Pulp and Power (now St. Regis) at Hinton.

The circumstance that makes Alberta's policy even more admirable is that the policy is motivated, not by a perceived shortage of wood products, but by a provincial commitment to sustained yield forest management.

The forest region of Alberta encompasses an area of some 39.1 million ha or approximately 60% of the total provincial land area. Timber harvesting is modest in comparison to other parts of Canada.

At present, the inventory indicates that we have 965 million m^3 of coniferous timber with an allowable cut of 14.1 million m^3 and an additional 580 million m^3 of deciduous timber with an allowable cut of 11.7 million m^3. Only 60% of the coniferous allowable cut is currently committed. A very small portion of the deciduous cut is being utilized. As a point of interest, the coniferous cut is increasing annually. The recently signed Forest Management Agreement with British Columbia Forest Products and the pending development of the Brazeau block, which will likely be finalized in 1982, will result in significant increases in use of the coniferous timber resource.

To a large extent, the success of reforestation in Alberta can be related to the realistic legislation that promotes reforestation on a shared basis between industry and government.

The sustained yield forest management concept was introduced in the province in 1956 with the signing of the first forest management agreement and was expanded in 1966 to the entire province. The objective of this management system was and is to ensure a perpetual and stable supply of wood fiber for the forest products industries. To achieve this goal, the annual timber depletion (harvest plus other losses) must be kept below annual net growth and all denuded land must be regenerated within a specified time period.

The annual allowable cut and rotation age for maximum yield are based on the assumption that all cutovers are satisfactorily regenerated within 10 years of harvest and that the productivity of the second-growth stands will at least equal the productivity of the original, unmanaged stands.

Reforestation Policy

1. All cutovers must be restocked 10 years after harvest, with year 0 being the year of harvest.
2. Some reforestation treatment is required within 24 months after harvesting.
3. Monitor initial success with a formal regeneration survey by the end of the 7th year.
4. Further treatment, if required, is mandatory in the 8th year.
5. Formal survey required to prove area sufficiently restocked by the end of the 10th year.

In addition to time frames set by policy, reforestation standards are essential to ensure that forest productivity is not diminished during the second rotation.

Reforestation Standards

1. Minimum of 790 evenly distributed trees per hectare (of acceptable species). Note: This means the *minimum* stocking standard; however, only one acceptable tree per plot is tallied, resulting in much higher tree densities.
2. Acceptable species: all native conifers with some limitation on alpine/balsam fir and hardwood species on coniferous cutovers.
3. Established age: minimum 2 years for pine, 3 years for all other species, and 3 years on site for planted stock.
4. A sufficiently restocked block may not contain unstocked areas larger than 4 ha.
5. All seedlings must be healthy, vigorous, and at least of minimum age.

Forest Tenure and Reforestation

In Alberta, timber is disposed of under three types of forest tenure, each with different policies governing reforestation responsibility. The majority of timber is harvested under the authority of forest management agreements and timber quotas, and a lesser amount under authority of short-term permits (local and commercial).

1. Forest management agreements
   a) Large integrated forest industries develop area.
   b) Fixed area.
   c) Set annual allowable cuts.
   d) 20-year renewable clause.
   e) Reforestation at forest management agreement owner's cost. Some forest management agreements state that the agreement holder must produce planting

stock at his own cost, while others require the government to produce the seedlings free of charge.

f) The government extracts, tests, and stores all tree seed free of charge.

g) Must follow provincial reforestation standards.

h) Intensive forest management clause.

2. Quotas

a) Share of annual allowable cut within designated management unit.

b) 20-year renewable quota certificates.

c) Timber licences issued for a 5 year period.

d) As each timber licence is issued, quota holders can opt to complete reforestation themselves or transfer reforestation responsibility to the government and pay a reforestation levy based on production (per thousand fbm).

e) Tree seedlings supplied free of charge.

f) All seed is extracted, tested, and stored by the government, free of charge.

3. Commercial and local timber permits

a) Medium and small short-term dispositions with no further tenure.

b) Reforestation levy charged.

c) Crown responsible for reforestation.

4. All timber harvesting prior to 1966, with the exception of forest management agreements and denuded land, becomes a responsibility of the Crown to reforest.

As previously mentioned, sustained yield forest management is based on annual timber depletion (harvest plus other losses) being kept at or below net annual growth, while all denuded lands must be regenerated within a definite period of time.

Normal reforestation for harvested lands is progressing very well under all tenures; however, forest land loss to other agencies and uses has proceeded almost unchecked. In order to compensate for this loss and maintain the present allowable cut, a new program commenced in 1979. This program compensates for three major losses in the productive coniferous land base: forest fire losses, industrial clearings, and special zoning, all of which total approximately 9300 ha annually.

The new program, called Maintaining Our Forests, is designed to create new forests on potentially productive land at the rate of 10 000 ha annually and to accelerate intensive management programs in existing forests and newly created stands. Stand improvement or juvenile spacing has been started on overstocked coniferous stands. The existing tree improvement program has also been accelerated. A small-scale program of wetland drainage has been initiated to investigate the feasibility of increasing the productive land base.

As you can see, all forest land tenure types and all major reforestation projects (such as Maintaining Our Forests) rely very heavily on the government nursery for high-quality planting stock.

Table 1. Reliance on government nursery capability

Tenure	% share of reforestation responsibility (area)	Trend	Government seedling supply (%)	Seed extraction, testing, storage by government (%)
FMAs	35	Increase	50	90
Quotas	25	Increase	100	100
CTPs and LTPs	5	Constant	100	100
Old cuts	10	Decrease	100	100
MOF	25	Increase	100	100

To meet current and future reforestation goals, the Alberta Forest Service has developed a tree seedling nursery that has a designed annual production capacity of 20 million seedlings. The facility has 20 greenhouses, which are capable of producing 10 million container seedlings in a single crop. The bare-root facility has capacity to grow 10 million seedlings annually, with additional land available to dramatically increase this production if required. Construction of this facility was started in the summer of 1977, and it is in full operation. This year (1981) slight expansions are being made to increase the capacity of this facility to 36 million to meet estimated future demand. The seedlings ordered by and produced for the forest industry and the Alberta Forest Service from this facility contribute highly to reforestation success.

The seed extraction facility and seed cleaning line at the nursery are capable of handling in excess of 18 000 hectolitres of cones per year. The seed cold storage facility is capable of storing 60 000 kg of seed and, at present, has some 40 000 kg in storage. Also located on-site is a propagation center for a cooperative tree improvement program with forest industry.

SUCCESS OF THE REFORESTATION PROGRAM TO DATE

All the above policies, particularly the legally mandated deadline for reforestation after cutting, have contributed to Alberta's very acceptable level of reforestation success. The significance of the classification of cutovers by years after cut is related to legislation:

> **0-6 years after cut** is considered to be the normal reforestation period or the time in which to treat areas to induce or enhance reforestation.

7-9 years after cut is mandated as the critical reforestation period. At 7 years after cut a formal assessment of reforestation success (called a regeneration survey) must be made; if the cutover is not successfully or sufficiently reforested, immediate remedial action must be taken.

10 years or more after cutting is the period legally considered to be past due for reforestation. A cutover area must be reforested to legislated standards by 10 years after cut or legal sanction can be applied. Thus, cutover areas 10 years (or more) old that are not reforested are treated as highest reforestation priority. (Table 2)

Table 2. Reforestation success in Alberta

Status of cutover area	Responsibility					
	Alberta Forest Service		Industry		Total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
0-6 yrs after cut						
Total	56 992	100.0	91 437	100.0	148 429	100.0
SR[1]	12 218	21.4	15 313	16.8	27 531	18.6
NSR[2]	44 774	78.6	76 124	83.2	120 898	81.4
7-9 yrs after cut						
Total	17 903	100.0	39 452	100.0	57 355	100.0
SR	14 544	81.2	23 111	58.6	37 655	65.7
NSR	3 359	18.8	16 341	41.4	19 700	34.4
10+ yrs after cut						
Total	38 100	100.0	72 788	100.0	110 888	100.0
SR	33 509	88.0	65 278	89.7	98 787	89.1
NSR	4 591	12.0	7 510	10.3	12 101	10.9

[1] SR denotes area satisfactorily reforested.

[2] NSR denotes area not satisfactorily reforested.

Aggregate Alberta Forest Service-forest industry reforestation success on cut areas 10 years and older is remarkably good; in all, 89.1% of the area harvested in this age group is successfully reforested. It is noteworthy that this age group of cutovers includes backlog areas harvested prior to the introduction of the formal reforestation policy in 1966. In real terms, 99 000 ha out of a total 111 000 ha cut are successfully reforested; thus, a backlog of some 12 000 ha require reforestation. It must be emphasized that a large proportion of these unregenerated areas have been treated, and in some cases more than once, but site conditions have prevented reforestation success. Furthermore, many of these areas are partially reforested but do not meet the legislated standard.

Of the 57 000 ha cut 7-9 years ago, 38 000 ha, or 66% of the area, have been successfully reforested. The success ratio for the cutover areas 7-9 years old has drastically increased over the past 4-5 years. This is the result of better and more immediate treatment of the harvested lands.

The recently harvested areas (that is, 0-6 years after cut) show 19%, or 28 000 ha, already successfully reforested. These areas have received early treatment and hence are successfully reforested to the legislated standards prior to the 7th year (mandatory survey time).

In summary, 99 000 ha (10 years and older) have been successfully reforested: industry and government combined have successfully reforested a total of 165 000 ha to sustain yield and, therefore, the flow of forest products for some years to come (Figs. 1-3).

The new ultramodern nursery at Pine Ridge makes reforestation much easier by providing a continuous supply of high-quality seedlings for Alberta's reforestation programs. The nursery plays a very important role in both government and industry programs as it supplies free extraction, cleaning, and storage of seed and free seedling stock to quota holders and some forest management agreement holders.

Finally, Alberta is gradually embarking on an intensive forest management program. This process is being undertaken carefully and thoughtfully. First, a forest tree improvement program in cooperation with the forest industry is well under way. Second, several intensive forest management operations such as thinning and fertilization are being examined and initiated on an operational scale.

These intensive management operations are being initiated prior to any shortfall in the wood supply and as a means to expand in the future beyond the current annual allowable cut.

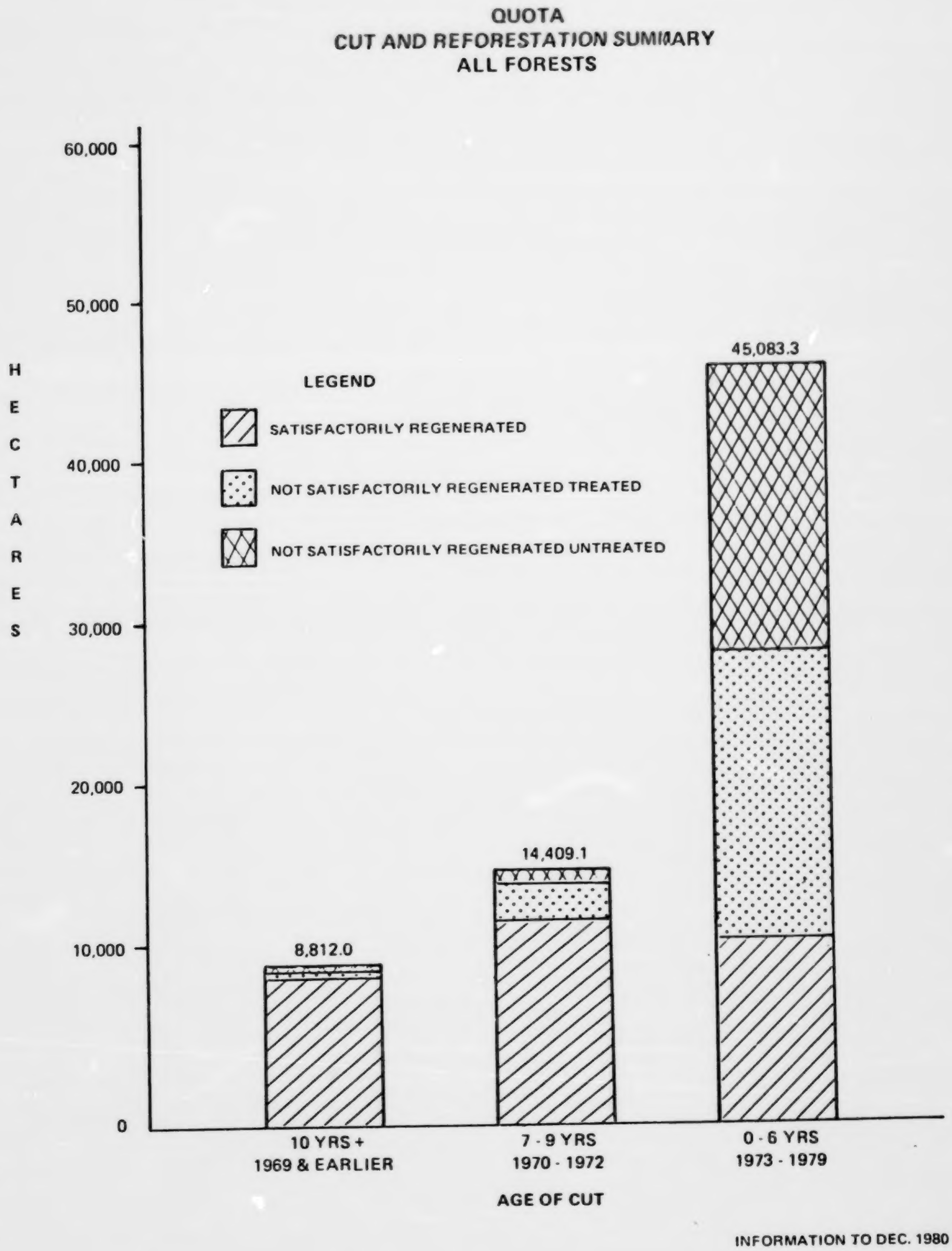


Figure 1. Quota cut and reforestation summary for all forests.

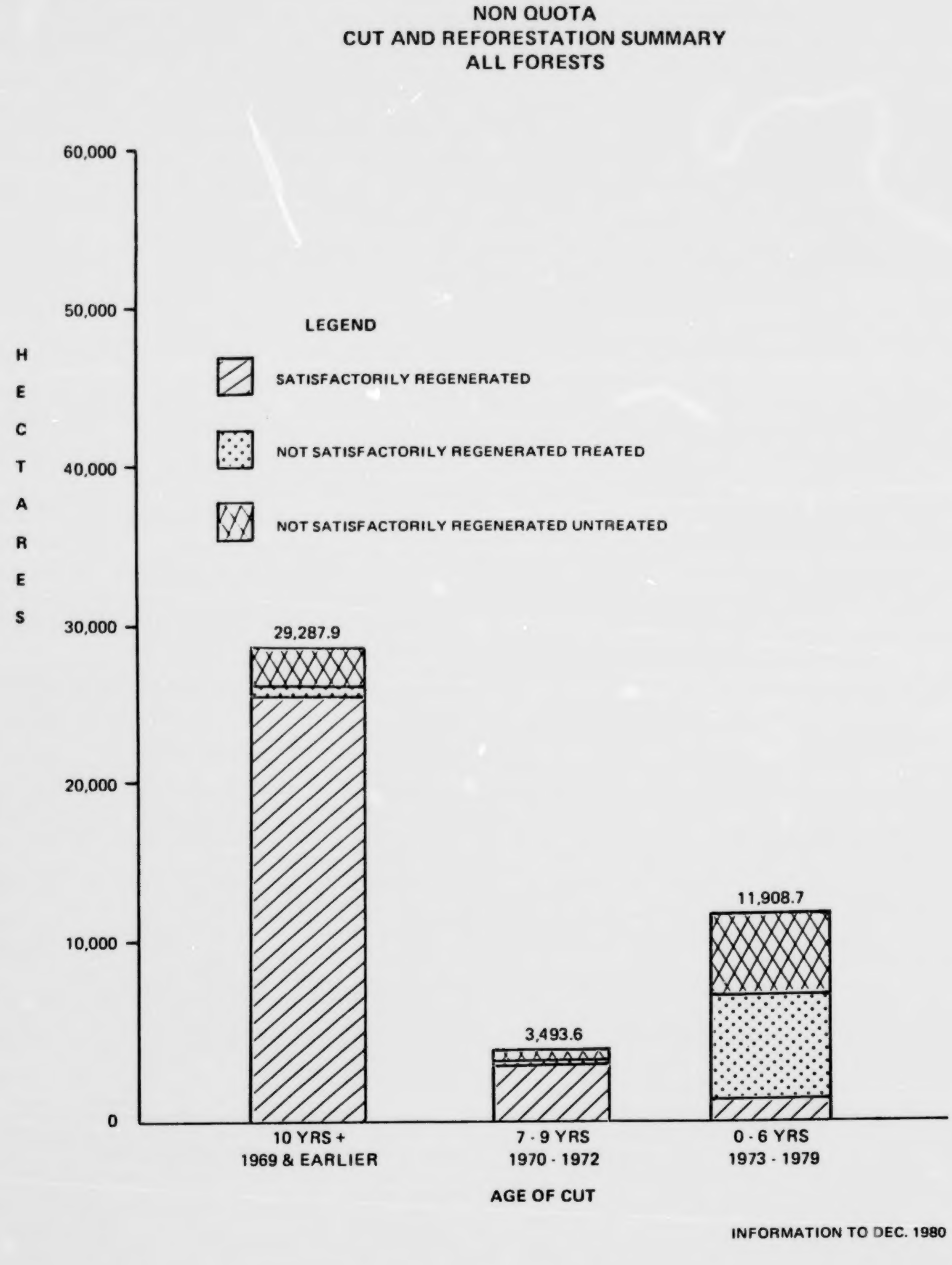
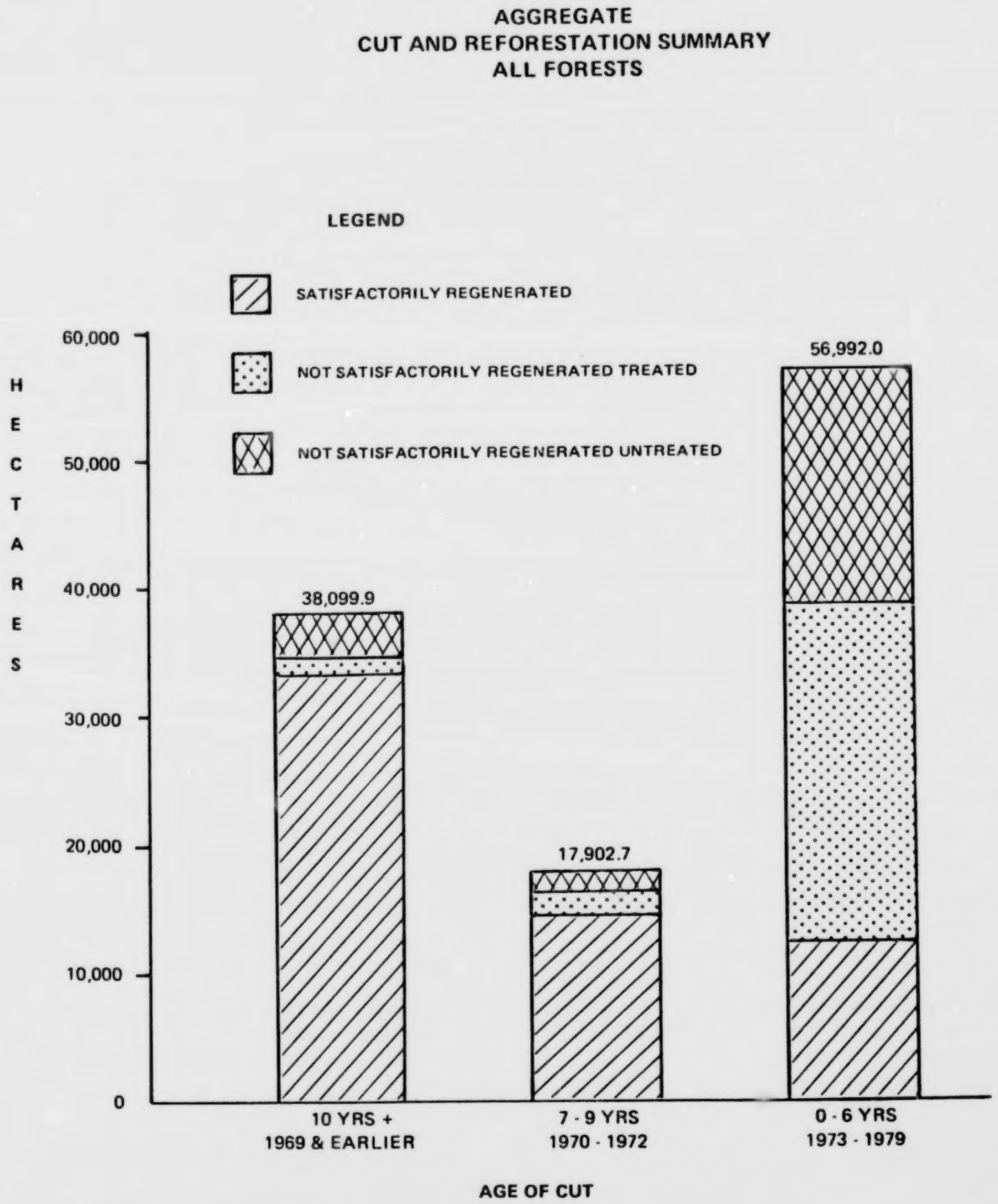


Figure 2. Nonquota cut and reforestation summary for all forests.



AGGREGATE
CUT AND REFORESTATION SUMMARY
ALL FORESTS

INFORMATION TO DEC. 1980

Figure 3. Aggregate cut and reforestation summary for all forests.

ALBERTA TREE NURSERY AND HORTICULTURE CENTRE

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The Alberta Tree Nursery and Horticulture Centre is a branch of the Plant Industry Division of Alberta Agriculture. This center and the Alberta Horticultural Research Centre, located in southern Alberta at Brooks, comprise the provincial government's program of support and involvement in horticulture. The Tree Nursery and Horticulture Centre is located approximately 3 km northeast of the present boundary of the rapidly expanding City of Edmonton. The grounds of the nursery occupy nearly one section of land. This extensive holding is used primarily for the production of planting stock, which Alberta Agriculture distributes to Alberta farmers and acreage owners through the shelterbelt program.

The first tree nursery, established in 1910, was under federal jurisdiction. In 1930, when the Province of Alberta assumed responsibility for the nursery, it was relocated to the Alberta Hospital. This site was inadequate for expansion needs, and it was moved to its present location at Oliver in 1949, hence the name Oliver Tree Nursery. During the last 30 years the grounds have expanded to their present size, with a net productive acreage of 220 acres. The nursery is open for public tours during weekdays. Anyone wishing a tour of the production facilities is encouraged to contact the nursery office.

DESCRIPTION

The permanent staff at the center consists of 30 technicians, 5 professional horticulturists, and 3 clerical workers. Seasonal workers are hired from April until December. During the busiest period the nursery employs up to 110 seasonal laborers. The most hectic time at the nursery is during the spring shipping of plant material. This is a 4-week period between April 20 and May 20. The second most active period is during October, when the plant material is harvested and graded.

During the late sixties and early seventies, all the buildings were replaced and new facilities were added. This renewal program is still continuing and additional storage and office space is planned. The present facilities consist of a packing shed and cold storage building, the seed extraction and seed storage facilities, and the machinery maintenance garage.

During Peter McCalla's long career as the head of the Horticulture Branch of Alberta Agriculture, he initiated the tree distribution program and coached the development of the tree nursery during the most hectic 25 years. Upon his recent retirement the arboretum and fruit orchard were named in his honor.

The nursery grounds are serviced with irrigation water from a storage reservoir of 30 acre-feet, which was created when the small Horse Hill Creek was dammed.

SHELTERBELT PROGRAM

The original function of the Oliver Tree Nursery was to propagate the plant material needed for the farm shelterbelt program. The production aim for the annual distribution is now 3.5 million seedling-sized plants. The establishment of farmstead windbreaks is commonplace throughout Alberta. A belt of trees around the farmhouse reduces the effect of the cold winter winds and by its shade and verdure creates a more pleasant environment for the farm family. The planting of trees and shrubs around the farmstead modifies air and soil temperatures and humidity. It protects the family and livestock from high winds, airborne dust, and drifting snow. It can also help reduce noise levels from adjacent roads as well as beautify the farmyard.

Establishment of field windbreaks is another important use of the planting stock distributed. Farmers can obtain the planting stock free of charge but are required to establish and maintain these plantings. The planting of field windbreaks helps control soil erosion, prevents the abrasive action of rapidly moving soil particles on tender seedlings, and reduces other harmful effects of blowing winds. Accumulation of snow behind windbreaks is beneficial for better retention of moisture, but it can also create problems if windbreaks are planted too close to traffic arteries. Wildlife plantings are occasionally requested, and some of the material is grown for this purpose.

The nursery distributes the plant material in the spring. An individual files an application for planting stock with the local District Agriculturist in the year prior to delivery of the planting stock. Processing of these requests is handled during the winter. In total, 33 tree and shrub species are propagated for the shelterbelt program. Smaller quantities of about 10 shrubs are propagated for wildlife promotion. Caraganas are produced in the greatest volume because of their usefulness in field windbreaks.

Most plants leave the nursery as 2-year-old seedlings, about 50 cm in height. The poplars and willows are 1-year-old rooted cuttings, while the conifers are 4-year-old transplants. All plant material is packaged in bundles of 10 for conifers and 25 for deciduous stock. The planting stock is graded prior to handling.

The agriculture zone of Alberta is subdivided into six regions. Every region consists of a number of counties or municipal districts. The county governments are directly involved in the shelterbelt plant activities. Tree planters are made available to farmers by county officials to assist in planting the seedling stock. In a few years time the newly planted shelterbelts will become functional and farmers will benefit from the protection they provide. The nursery recommends planting multiple-row shelterbelts and using conifers as part of the farmstead shelterbelt layout. This will make the windbreak more effective during the winter. Clean cultivation of the shelterbelt margin prevents weeds from becoming a problem. Nursery staff are available to help farmers design windbreaks and to plan their farmstead.

The actual growing of the shelterbelt plant material takes place in designated fields of the nursery. The soils of the nursery are of a heavy-textured black clay loam. Because of the heaviness of this soil, it is not ideally suited for nursery crop production, but the soil is fertile and proper management keeps it arable. As a rule, a nursery crop stays on the same field for 2 years. If a field is very heavy, run down, or infested with weeds it will be seeded to grass and left this way for a few years.

The normal rotation procedure is for a field to be in production 2 years and then given 1 year of rest. During this fallow season, the field will be given a dressing of peat moss, which is then rototilled into the soil. The field is seeded to oats, which is plowed under that same summer.

The deciduous stock is seeded in the fall, usually in the first week of October. Crops are row seeded, six rows to a seedbed. Since most seeds are stratified, a great deal of the seeding is done by hand. The seeded beds are covered with a light dressing of sand. An underground irrigation system is in place to maintain optimum moisture conditions. In 2 years these crops are mature and ready for harvesting.

In the past, coniferous plants were also seeded outdoors in seedbeds; however, the coniferous seedlings are now raised in containers. The survival rate of these container-grown transplants is close to 100%. Transplanting of spruce and pine starts in the middle of August and is usually completed by the second week in September. This planting stock will be harvested 3 years later. The fields are irrigated if rainfall is inadequate.

The propagation of willows and poplar by hardwood cuttings is another major activity in the plant propagation program. A stock of willow and poplar is kept at the nursery. In late September, year-old whips are tied in bunches before harvesting. The whips are harvested in the winter and cut into 15-cm sticks. The nursery requires approximately 1 million hardwood cuttings in order to produce 700 000 rooted cuttings the next fall. The cuttings are hand planted. This activity takes place from the end of May until the second week in June. Irrigation is utilized until sprouting of the cuttings is well established. Poplar cuttings can grow to a height of 3 feet before the middle of October. From the end of May until September, weed control is the most labor-intensive activity at the nursery.

Preplanting treatments of herbicides is a common practice for weed control. Chemicals may also be used on the established 1-year-old plants. Mechanical weed control is used on the established 1-year-old crops and transplants and has the advantage of breaking up the soil crust that readily develops on these heavy clay soils. Hand weeding is always a big job on the newly seeded fields. This can be a problem during extended wet periods when the weeds have an opportunity to get ahead of the nursery crop; however, the seedbeds are usually cleaned up during June.

The harvesting of all deciduous stock begins in October. Prior to hand lifting the crop, the plants are undercut with a shaking blade. The taller crops are cut back with a chopping machine that removes the upper portions of the plants. This results in plants with maximum heights of 50 cm. This plant material is then graded, bundled, and counted prior to storage. Stock is both outdoors and indoors. The heeling-in grounds contain about one-half of the crop by the middle of November. The remainder of the crop is stored in pallet boxes in a temperature-controlled building, where temperatures are maintained around 0°C. The roots are protected with a layer of peat moss.

Shipping of the plants usually starts the last week of April. The plant material, with moist peat moss around the roots, is wrapped first in polyethelene and then burlap. Each bundle is addressed to the individual farmer. The county officials collect their district's orders at the Alberta Tree Nursery and then distribute them to the farmers from their office. The nursery deals with about 75 districts in this manner.

An important segment of the nursery operation is the equipment maintenance garage, which is operated by three machinery maintenance mechanics. In addition to the maintenance and repair work, the garage workshop also builds specialized equipment.

The irrigation supervision and coordination are handled by one person. The nursery employs five gardeners and two supervisors, who are responsible for all tractor and spraying operations and shelterbelt maintenance.

PROVINCIAL PARKS PROGRAM

The provincial parks program is much smaller than the shelterbelt program. This material is all grown in large containers, either 1-, 2-, or 5-gal pots. The provincial parks organization requires larger planting stock 1 to 2 m in size. To maintain the natural settings of the parks, only native material is grown for this program. The management of the greenhouses is the responsibility of the technician in charge of the provincial parks program. The greenhouses are of a Quonset type and are heated with natural gas furnaces.

The basic container used for the greenhouse propagation is the Spencer-Lemaire container, also call a root trainer. This is a thin-walled, hard plastic container that opens up like a book. Different sizes of the container are available. The size of the container used is based on the needs of individual species. The major crops grown in the greenhouses are coniferous plants. A crop will be grown during summer or winter for a period of up to 7 months, after which the plants are hardened off in lathhouses covered with shade cloth.

The containers are sown with several seeds per cavity. The number of seeds is based on the germination tests. This procedure then requires hand thinning of the seedlings. Irrigation and fertilizer applications are automated. Natural light during the winter moths is supplemented with artificial lights. Weed and pest control are necessary. When the seedlings are transplanted into large containers they are moved to the lathhouses. The plants are watered with overhead sprinklers, and shade cover is provided.

Large-sized container production is rapidly expanding in Alberta; however, we have little experience in this area of nursery production. The key to success lies in the ability of the plants to survive the winter months. The nursery is continually improving its overwintering procedures. Good cover is essential.

All seeds used in the propagation work are collected and cleaned by the nursery. In order to have a reliable supply of seed every year, a seed bank with a minimum of a 3-year supply of most seeds is maintained. The seed extraction plant was once heavily involved in a reforestation program. Every year seeds from thousands of bushels of spruce and pine cones were extracted. This activity has now been transferred to the Pine Ridge Forest Nursery at Smoky Lake.

The Alberta Tree Nursery has a well-equipped seed lab where all collected seeds are tested for seed viability. Seedlots are prepared for seeding through stratification. The nursery maintains a program of seed sales to commercial nursery operators. A seed exchange service with other stations is maintained. Some seeds are difficult to germinate. The nursery is continually searching for solutions to these problems. Different methods of stratification and different times of seed collecting are two areas under investigation.

OTHER ACTIVITIES

Applied research is another aspect of the nursery operation. The research program delves into various production problems. Other areas of applied research conducted at the nursery include the response of seedling stock to various fertilizer applications and the screening of herbicides for nursery use. Decreasing the mortality rate of stored planting stock is another ongoing project.

Another area of investigation is the vegetative propagation of bush fruits and woody ornamentals. As a consequence of this work, the nursery was assigned the task of producing a large number of Saskatoon plants for the Peace River Fruit Growers. Interest in this native fruit has resulted in the development of improved cultivars, which are now being vegetatively propagated. Saskatoon softwood cuttings root readily, but the plants tend to go into a deep dormancy after the initial rooting. The nursery is examining various ways of breaking this dormancy. The research section has also done a considerable amount of work on finding improved ways of rooting native junipers.

Research on vegetables is a recent addition to the activities of the Alberta Tree Nursery and Horticulture Centre. One ongoing project is the evaluation of mulches and plastic tunnels on a variety of vegetable crops. In our cold northern climate, plastic mulches have proven to increase yields and advance the date of harvesting by controlling soil temperature and conserving moisture.

Miscellaneous plant propagation activities include the production of Arbor Day trees, production of seedlings for Indian Affairs, and the provision of planting stock for municipal parks. The Arbor Day program entails the annual production of approximately 40 000 Colorado spruce seedlings for the school boards. Many of the ornamental blue spruces in Alberta are a result of this program.

Finally, the Alberta Tree Nursery and Horticulture Centre maintains orchards for fruit testing and seed collection and an arboretum. Alberta is not an area noted for its tree fruit growing, but a half century of plant breeding has resulted in the selection of a number of hardy apples, crabapples, plums, and apricots. The test orchard at the nursery includes many of the hardy apples and plums. The nursery continues to monitor the performance of these trees. This orchard will be gradually expanded to cover a 2-acre site.

The seed orchard was established to provide a source of seed for the shelterbelt program. The 3-acre arboretum is another test site for the shelterbelt program. The performance of the trees and shrubs is recorded. This arboretum will also have an extension function. Once it is fully established, applicants for the shelterbelt program will have an opportunity to view mature specimens.

Other extension activities include pruning workshops. Several workshops are offered throughout the province by the professional staff of the Alberta Tree Nursery and Horticulture Centre. The Horticulture Branch, through the District Agriculturists, offers courses to amateur gardeners. These courses are coordinated by the nursery. The staff serve as resource people for these courses. They also provide information to commercial vegetable growers, nursery operators, and sod growers.

The Alberta Tree Nursery and Horticulture Centre offers services in the areas of production, research, and extension in order to achieve greater economic returns and to improve the quality of life for Albertans.

REFORESTATION RESEARCH IN THE PRAIRIES: AN OVERVIEW

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Edmonton, Alberta

INTRODUCTION

As the title suggests, my assigned task this morning is to talk to you about reforestation research activities in the three prairie provinces--Alberta, Saskatchewan, and Manitoba. Owing to the diverse backgrounds and the wide geographical distribution of the members of the Intermountain Nurserymen's Association, I thought it appropriate to spend a few minutes at the outset of this presentation to familiarize you with the region and to briefly outline the role of the Canadian Forestry Service as a research agency. Such an overview will, I hope, make it easier for you to relate to my comments about reforestation research.

The Canadian Forestry Service (CFS) is an element of Environment Canada. The Northern Forest Reserch Centre (NoFRC) is one of six regional establishments and two national institutes responsible for fulfilling the federal role in forestry research, development, and technology transfer. Today, the NoFRC serves a vast area lying north of the US border between the Rocky Mountains in the west and the province of Ontario in the east, totalling 3 120 000 km^2 (1 200 000 sq. mi.) of land area in the three prairie provinces and the Mackenzie District of the Northwest Territories. About one-third of this land mass, or 1 040 000 km^2 (400 000 sq. mi.) is classified as being forested, roughly equivalent to the combined areas of the states of Montana, Idaho, Utah, and Wyoming.

The NoFRC maintains work programs in Forest Resources Research, Environmental Forestry Research, and Forestry Extension and has an Administrative Services Unit, for a total of 117 person-years. In the Forest Resources Research Program, projects include Silvicultural Prescriptions, Tree Improvement, Fire Management Systems, Resource Policy Guidelines (Resource Economics), Forest Resource Data, Yields of Managed Stands, Forest Resource Management Options, and Computer Applications. Projects in the Environmental Forestry Research Program are Forest Hydrology, Long-Range Transport of Air Pollutants, Remote Sensing, Toxic Substances, Climatic Studies, Biophysical Classification of National Parks, Scientific and Technical Information, and Environmental Impact Assessments. Forestry Extension activities include the Forest Insect and Disease Survey, Insect and Disease Management Systems research, and various laboratory services. Major clients include provincial forest services and environment departments, commercial tree nurseries, lumber companies, pulp and paper firms, national and provincial parks, and other federal government departments.

REFORESTATION RESEARCH

Management of forest lands on a sustained yield basis is accepted as a desirable objective by all provincial resource management agencies. Failure to regenerate forest lands after harvest or wildfire in the past has resulted in reforestation shortfalls, particularly in the mixedwood forest region. Happily, the problem has been recognized and regeneration programs are increasing rapidly. New forestry leases and agreements, such as the Forest Management Agreements (FMAs) in Alberta, contain stringent reforestation requirements. Similarly, the establishment of additional forest tree nurseries in recent years has resulted in a substantial increase in the production of containerized seedlings. In the area of reforestation research, the primary objective of the CFS is to provide forest management agencies with guidelines and prescriptions for prompt regeneration and growth of major commercial species and/or cover types. The actual work may range from basic to operational, according to needs of client agencies and the nature of reforestation activities in various parts of the region. I consider the following to be highlights of our reforestation research and technology transfer program in the prairies.

Nursery Operations

Liaison with and service to both government and industrial nurseries across the region are provided by this study. During the 5-year period ending in 1980, the rapid expansion of nursery and greenhouse facilities has resulted in a three-fold increase in seedling production to over 50 million, with the result that the work is particularly relevant and in high demand in support of both bare-root and container production facilities. Regional nurseries are surveyed for problem identification and assessment, and recommendations are made to improve facilities and production schedules.

There is evidence that outplanting mortality is related to both cultural and pathological problems in the nursery system. The handling of seedlings, disease and weed control, improvements in cultural operations, and development of new techniques for seedbed treatments are therefore likely to contribute substantially to improved nursery practices. New work is under way to determine seedbed density effects and to develop a method for mechanical thinning of seedbeds.

Nursery Soil Fertility and Seedling Growth

This study is concerned with the growing of bare-root and containerized coniferous stock under different fertilizer regimes and cultural practices to optimize production. Recent studies have dealt with seedling nutrition and soil amendments regarding the use of N, P, K, S, and peat. Recommendations have enabled nursery managers to use fertilizers more effectively and to improve stock quality. A manual entitled "Guidelines for Rearing Containerized Conifer Seedlings in the Prairie Provinces" has been published and is in widespread use throughout the region.

Current work stresses research and advice on production factors such as the growing medium and the use of water and fertilizers in both bare-root and container stock. Special emphasis is being placed on the maintenance of seedling quality throughout the production cycle. Since regional nurseries have recently expanded their operations, research and advisory services pertaining to soil fertility and tree nutrition have been stepped up accordingly.

Storage of Winterized Containerized Conifer Seedlings

Containerized seedlings are reared throughout the year; those reared in spring and summer, but not planted in the year of production, need to be stored over winter. This study addresses problems of preconditioning and storage of stock to reduce winter damage, a problem of particular importance in pine.

Any program to increase the availability of seedlings for reforestation should provide 1) flexibility and safe storage of seedlings, 2) ease of handling of containerized seedlings, 3) an increased capacity for seedling production, and 4) protection against frost injury and dessication. Recent and ongoing research work includes the assessment of growth characteristics and mortality before and after outplanting and overwintering of pine and spruce seedlings in field demonstration plots. A new experimental seedling storage facility has been constructed and tested and has been found to be effective in reducing temperature fluctuations. A manuscript outlining guidelines for overwintering container stock is being prepared and will include a section on the detection of frost damage in coniferous seedlings.

Development of Silvicultural Prescriptions

The need for site-specific prescriptions to improve success of reforestation and to maintain the long-term productivity of forest sites in the region is assessed in this study. We have concluded that a good deal of information needed to upgrade silvicultural practices in the region is already available but must be packaged in a form to be of optimal use in support of forest management decision-making. Efforts are under way to establish a silvicultural data bank, including the development of criteria for judging utility and reliability of research and operational data and for aggregating stock performance data. In a related development, the NoFRC has assumed responsibility for the establishment, maintenance, and updating of a data bank on site preparation, regeneration, prescribed burning, and stock performance for all regions of Canada. This data is being assembled with the assistance of provincial forestry agencies and will become an integral part of the national Forest Resource Data Program.

At present, a silviculturalist, a site productivity specialist, and a physiologist are assigned to the silvicultural prescriptions project, the latter two at an early development stage of research work. The site specialist will be concentrating on forest site relationships, initially using biogeoclimatic data as one aspect of field study. The physiologist will probably concentrate on seedling conditioning and field performance, with emphasis on roots.

Field Performance of Planted Stock

This study is aimed at documenting the growth rates and survival of forest plantations throughout the region, providing background information for reforestation prescriptions. The work involves cooperative research trials with provincial agencies and pulp and paper companies as well as in-house research.

Research plantations of bare-root stock were established in this region as early as the 1920s and continued into the 1950s by the CFS and its predecessors. The oldest are located in Manitoba and Saskatchewan, and several are still intact. By the early 1960s emphasis was directed to container planting, and several research and trial plantations were and continue to be established. Performance data are available for a number of container types with various rearing regimes for periods up to 20 years.

While these older plantations are most useful for determining performance on a variety of sites for a number of coniferous species, both native and exotic, there are problems associated with stand dynamics that still require research. The impact of losses due to insects, diseases, animals, and climate has not been fully documented. In some cases ingress occurs after reforestation. These factors must be considered when determining initial spacing and juvenile thinning regimes. Studies to document these losses have been initiated in Alberta and Manitoba.

Performance data are necessary as input to intensive forest management simulation models currently being developed. Although existing research plantations will be helpful, there is a need for the establishment of many more plots or trials to provide a data bank of performance information, including all usable CFS research plots, which will permit accurate determination of future yields on forest lands. Subsequently, a new study has been initiated to assess tree mortality attributable to insect and disease attacks from time of plantation establishment until crown closure at age 25 to 35 years. An estimate of this mortality will be obtained by establishing plots in a number of stands of different age classes and on a variety of sites. The intent is to prepare composite survival curves for each site to gauge pest damage in plantations and to determine the feasibility of obtaining quantitative estimates of these effects on tree mortality and growth loss.

A new study is also under way to determine the amount and quality of seed available, particularly for white spruce. Seed production and quality are known to fluctuate markedly from year to year. In years when the cone crop is light, insect and disease damage is often severe and results in over 90% seed destruction. The study involves the collection of cone samples from seed producing agencies in the prairie provinces, cone dissection, and the identification of insect pests causing the damage. This information will help us to assess the severity of the problem and to devise remedies before forest managers demand immediate answers in support of intensive management.

Control of Pests and Vegetation in Managed Stands

The development and assessment of the use and effectiveness of herbicides and pesticides as forest management tools are being investigated. From 1972 to 1979, efficacy tests were conducted with numerous insecticides, and sufficient data have been submitted for the registration review of 22 chemical products for the control of 33 insect pests attacking 22 species of trees and shrubs.

The release of conifers from brush, weed, and grass competition is a serious concern in the prairie provinces, especially in the mixedwood region. We have recently initiated, in cooperation with the Alberta Forest Service (AFS), small-scale field trials to evaluate the effects of selected herbicides on competing vegetation. Preliminary assessments have been made at all test plots established in 1980 and 1981 to monitor results of conifer release, site preparation, and artificial (chemical) thinning following different application dosages, formulations, and techniques. Various formulations of Velpar have given generally good to excellent control of unwanted vegetation on conifer release sites. Hyvar shows potential for chemical thinning of dense pine stands. Foresters consider herbicides to be a very promising tool, but care must be exercised to ensure that adverse environmental impacts and public health hazards are at acceptable levels.

Tree Improvement

This project includes a) plantation performance experiments on genetic variation within forest species among populations of varying origins (provenance experiments initiated from 1955 to 1972) and b) a breeding program initiated in 1967, intended to increase productivity of jack pine plantations by means of genetic improvement. About 90-95% of project resources are expended on the jack pine breeding program.

Progress on the breeding program has included selection of parent trees; establishment of twelve replicated family-test plantations; establishment of two preliminary clone banks, a permanent clone bank, and a seedling seed orchard; selection of about 50 parent clones top-ranked for fifth-year progeny height in the family tests, production of seed orchard grafts of the selected clones for use by client agencies; and selection thinning of the seedling seed orchard. Preliminary results indicate a 12% gain in height growth attributable to genetic selection. A comprehensive report on the program is being prepared.

Activities in the next 3 years will include measurement of family-test plantations at 10 years from planting; controlled pollination followed by seedling clone production, as well as grafting; using selected parent and progeny clone bank grafts, and analysis of family test data to refine breeding tactics and strategies in order to maximize genetic gain.

Yields of Managed Stands

With increasing forest harvesting in the region, the need is increasing for reliable information on growth and yield of stands under a variety of conditions. We continue to collect such data from growth-plot remeasurements and to analyze and publish the information as yield tables or models. Yield tables for the most important commercial forest types in the region have been developed. Work is now in progress to develop, or adapt, computerized growth simulation models for our stands, to be used for growth and yield predictions in updating forest inventories as well as for predicting the outcome of various silvicultural treatments.

At present, two stand treatments are of particular interest to us for improving merchantable yield: a) thinning, b) fertilization. Studies are in progress to obtain information on growth response to different treatment levels in lodgepole pine, jack pine, and aspen. A major part of the effort is concentrated on lodgepole pine, a commercially important species that often regenerates in over-dense stands. In such stands, tree growth is reduced and early thinning offers an opportunity to as much as double merchantable yield at harvest. We are monitoring growth response after both selective and nonselective (mechanical-strip) thinning of different intensities, the latter being a low-cost approach.

As in agriculture, mineral fertilization in forestry can play an important role in improving crop yields. We are conducting studies in lodgepole pine to give us some answers as to what age, site, and nutrient combinations would give optimal response and final yield.

With ever-larger areas of forests being harvested each year in the region, the level of initial stocking of regeneration and the spacing distance in plantations assume great importance in terms of both establishment costs as well as consequent growth and yield of the new stands; therefore, standards for regeneration have been developed. NoFRC scientists are involved in a cooperative study with the AFS to gain better insight into the dynamics of ingress and regeneration development under different conditions to enable us to refine stocking standards. Studies are continuing into stand development at different initial spacings--for lodgepole pine in Alberta and jack pine, red pine, and white spruce in Manitoba.

In addition to these ongoing programs in growth and yield, some pressing problems arise from time to time that require immediate attention. For instance, just now we are involved in a study, requested by the AFS, to assess tree growth response to openings in the forest for pipelines and seismic lines. We want to find out the overall effect of such openings on growth and yield per total area--including the opening.

Coordination and Future Direction of Reforestation Research

Silviculture research conducted by the provinces is operationally oriented. Field performance studies are done for all nursery stock shipped out in one of the provinces. Intermediate stand treatment research is being maintained and expanded, particularly in the area of juvenile spacing of pine. The Alberta Forest Service supports contract research through the Forest Development Research Trust Fund.

A regional Reforestation Technical Committee provides communication and coordination between federal and provincial silviculturalists in matters of research needs and priorities and development of operational reforestation programs.

Increased emphasis on reforestation research in the prairies is seen as a high priority area. The current emphasis on regeneration, covering stock production through to field performance of new plantations, involves about 15 scientists and support staff at the NoFRC. Should new resources become available in the near future, new or expanded initiatives will probably include studies of forest ecology relationships (including aspen and peatlands), mixedwood silviculture, use of herbicides in forest management, development of reforestation prescriptions and growth and yield models for managed stands, and possibly shelterbelt management. Implementation of any new programs will be carried out within federal-provincial forest research agreements now being developed with Alberta and, we hope, with Saskatchewan and Manitoba in the near future.

COLD HARDINESS TESTING OF CONTAINER SEEDLINGS

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Successful greenhouse production of containerized forest tree seedlings requires high rates of transplant survival. Low temperature is one of the environmental stresses that the seedling must be able to tolerate, so cold acclimation is an important aspect of the production cycle. Unfortunately, there are currently no convenient methods for determining when a particular lot of seedlings has attained the level of hardiness that will allow survival. The rate and extent of hardening vary between species and probably between some seed sources of the same species; certain production variables also influence the hardening process. Many nursery management decisions are made more difficult by this uncertain status of tree seedlings. Researchers and nurserymen need a rapid, convenient means of accurately measuring the cold hardiness of nursery-grown tree seedlings.

We are interested in the possibility that differential thermal analysis (DTA) may provide a convenient, rapid estimate of tree seedling cold hardiness and dormancy. DTA is a method of measuring patterns of freezing in plant tissue. To understand its potential value as a measure of hardiness, it is necessary to briefly review relevant mechanisms of cold resistance.

COLD HARDINESS

The various ways that plants resist the effects of cold stress have recently been reviewed by Burke *et al.* (1976) and described in more detail by Levitt (1980). To avoid injury, a plant must avoid the freezing of intracellular water in crucial tissues, since such freezing is fatal to the affected cell. North American tree species avoid the freezing of water in living cells by

1. supercooling to temperatures as low as -40°C (water in xylem and extracellular spaces does freeze), or
2. movement of freezable water from the cell to extracellular ice (such plants tolerate extreme cellular dehydration and survive very low temperatures).

As trees harden, their capacity to supercool and/or to withstand the presence of extracellular ice and cell dehydration increases. Although cell water in some tissues may supercool, other tissues of the same plant exhibit the second hardiness mechanism. Tree tissues that are known to supercool include buds and xylem ray parenchyma.

Hardiness limits are imposed by the killing point of the most sensitive tissue. In supercooling species, hardiness limits are -40°C (or slightly lower), since this is the theoretical limit for supercooling (of pure water). When water crystallizes after extensive supercooling, it freezes very rapidly and is instantly fatal. The hardiness limit imposed by the supercooling mechanism is well correlated with native plant distributions (Becwar 1980, George *et al.* 1974). Buds do not typically supercool as much as do stems;

the killing point for buds of fully acclimated trees is usually no lower than -30°C (Sakai 1978).

Trees that deep supercool include commercially important conifer and hardwood species. There have been essentially no studies of supercooling in containerized nursery stock. The characteristic is of special interest here because the DTA technique provides a precise measure of the freezing temperature of supercooled water and thus the cold hardiness of the tissue.

DIFFERENTIAL THERMAL ANALYSIS

DTA is a calorimetric method based upon measuring the heat evolved as water freezes; the freezing of water is an exothermic process. To characterize freezing patterns in plant tissue pieces, two thermocouples are used in series (Burke *et al.* 1976). The first thermocouple is enclosed in a small chamber, adjacent to the tissue, while the other serves as a reference. A small aluminum block holds the thermocouples, and the whole system is cooled at a known rate. The temperature difference between two thermocouples (sample and reference) is continuously recorded. As water freezes, a sharp increase (exotherm peak) occurs because sample temperature rises while reference temperature remains the same. Typically, a large initial peak is observed; this represents the freezing of extracellular water, and except in very tender tissue, does not cause injury. The freezing of supercooled water results in a second exotherm at progressively lower temperatures in hardening plants; this is called the low temperature exotherm (LTE) and is associated with injury (Fig. 1).

The advantages of DTA for measuring freezing patterns and, potentially, for applied practical determinations of seedling hardiness include close correlation between LTE and low temperature killing points; simplicity; speed--a run can be made in less than an hour; small sample size; and large possible sample number.

DTA AS A NURSERY TOOL

Several observations from the literature suggest that efforts to develop DTA as a practical technique can succeed. These include the fact that DTA provides an objective, precise measurement (the temperature of the LTE) that closely matches the tissue killing point (Becwar 1980, Burke and Stushnoff 1979). In addition, the LTE shifts and occurs at a progressively lower temperature as woody plants acclimate (Sakai 1978, Becwar 1980). There is a precedent for considering the practical application of DTA in the work of Proebsting and Sakai (1979). They measured peach flower bud hardiness and evaluated DTA as a tool in orchard management.

The objective of our work is to obtain data needed to develop DTA as a method of measuring cold hardiness (and dormancy) of forest tree seedlings. We plan to compare the DTA profiles of selected tissues from species of commercial importance and to observe changes correlated with conditions that alter hardiness. Terminal buds appear to be especially promising as test tissue, mainly because of sampling ease/uniformity and their well-defined DTA profiles (Sakai 1978). In preliminary experiments we observed that the bud LTE of containerized Engelmann spruce occurred at lower temperatures as hardening progressed. We did not find supercooling in bud or stem tissues of several pine species tested; however, the needles of certain pines have been reported to show an LTE in DTA profiles (Becwar 1980).

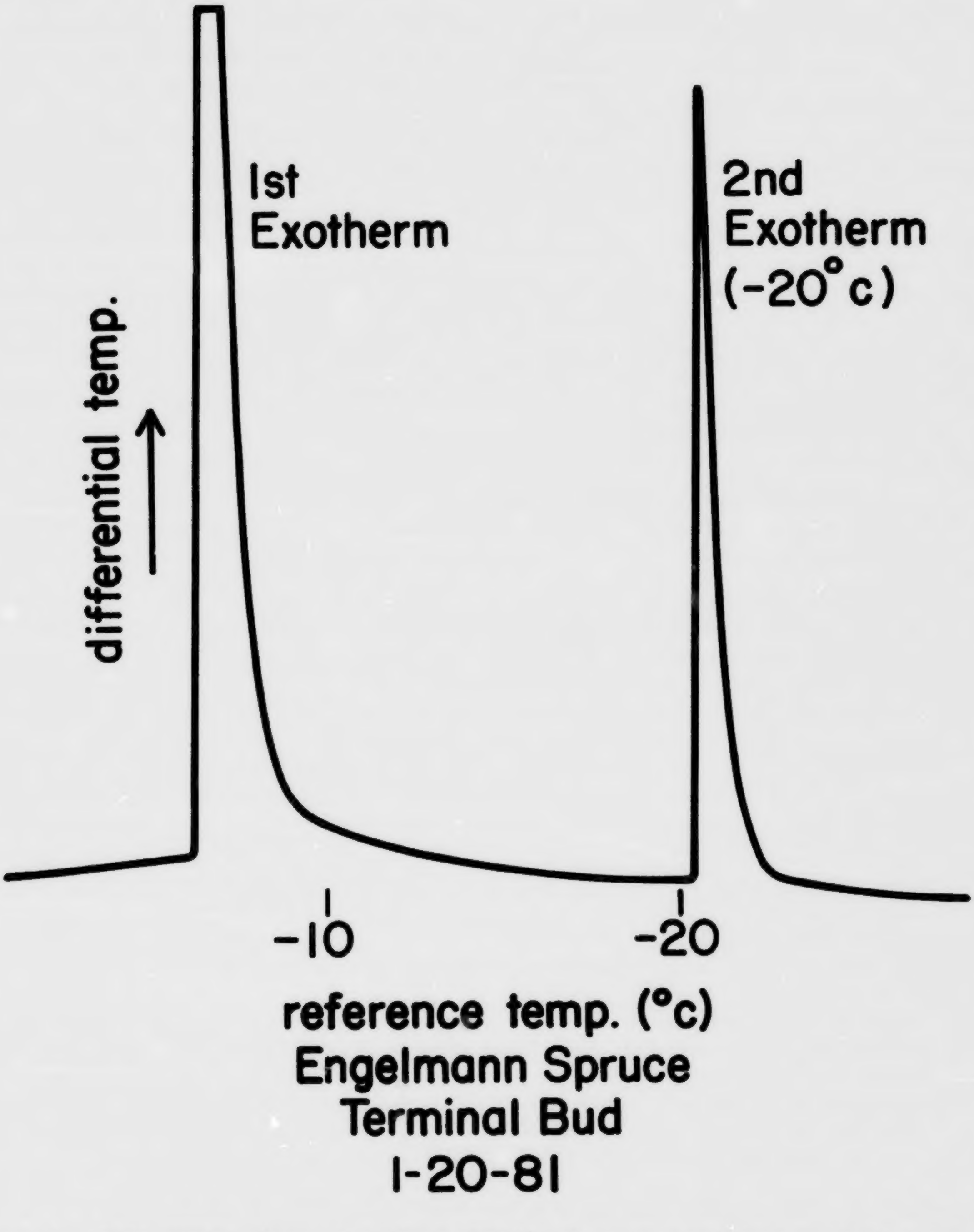

Figure 1. Differential thermal analysis (DTA) of a terminal bud excised from an Engelmann spruce seedling in January 1981. The low temperature exotherm (LTE) occurred when the bud reached -20°C. The LTE represents the freezing point of supercooled water and the low temperature killing point of the bud.

As pointed out earlier, supercooling is not a part of frost resistance in all woody plants. Clearly, the absence of this feature imposes a potentially serious restriction upon the widespread use of DTA as a nursery tool. Supercooling must occur if DTA data are to be used in this way. The major limitation evident from the literature is the apparent absence of supercooling (and thus LTE) in most species of *Pinus*. On the other hand, tissues of many conifers do contain supercooled water when in the hardened state. These include essentially all *Abies* and *Picea* species that have been examined, as well as members of *Juniperus*, *Larix*, and other genera. In addition, the buds of Douglas fir are known to exhibit well-defined peaks (LTE) on DTA profiles.

There are many practical situations in which decision making would be simplified by the "on the spot" measure of hardiness that DTA might provide (Table 1). The central idea of this project is to determine if DTA can predict--quickly and easily--the temperature seedlings can be expected to tolerate at any point in the production cycle.

Table 1. Examples of possible applications of differential thermal analysis (DTA) data as a nursery management tool.

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1. Determination of lifting schedules
   Knowing that seedlings are hardened enough to withstand subfreezing storage would be valuable information.
2. Evaluation of seedling hardiness for fall plantings.
   Species/seedlot differences make arbitrary "calendar date" decisions difficult.
3. Measurement of hardiness as a guide to moving seedlings between greenhouse and unprotected environments.
4. Monitoring changes in hardiness (and dormancy) during cold storage.
5. Permitting "certification" of seedling hardiness for marketing purposes.

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SUCCESSFUL OVERWINTERING OF CONTAINER-GROWN SEEDLINGS

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ABSTRACT

Ponderosa pine, Scots pine, bur oak, green ash, and seven other hardwood species were successfully overwintered at Bottineau, N.D., buried under snow or moderately dry peat in unheated white plastic or snow-fence covered structures. Several other environments were intermittently successful or failed. Measurements of temperature and water stress to determine cause of success or failure were inconclusive.

In cold climates, container nurserymen have frequently raised beautiful seedlings only to have them ruined during overwinter storage (Zalasky 1977). The principles of overwinter storage are well known in outline (Sakai 1970, Williams 1974, Blackler 1974, Burke *et al.* 1976, Havis and Fitzgerald 1976, Fretz and Smith 1978), but there is little specific information on economical environments in which to overwinter container-grown forest tree seedlings in cold climates (Owston and Stein 1977, Carlson 1979).

There are three causes of overwinter damage, the most obvious of which is low temperature (Havis 1976, Sakai 1978, Studer *et al.* 1978, Desjardins and Chong 1980, Gouin 1980). Container seedlings are more susceptible to damage caused by low temperature than are bare-root seedlings in nursery beds, because the roots, the most sensitive part of the seedling, are above ground. To avoid damage, seedlings must have had adequate time under proper conditions to harden sufficiently, and they must not be exposed to lethal temperatures.

Another cause of overwinter damage is desiccation. When the root ball is frozen, seedlings may not be able to replace moisture as fast as it is lost (Davidson and Mecklenburg 1974, Wiest 1980). Preventing freezing of the root ball to avoid desiccation may be very expensive. Alternatively, loss of water can be retarded by using moisture barriers and minimizing temperature fluctuation or perhaps by supplying moisture to the tops as well as the roots (Havis 1976, Wiest *et al.* 1976, Smith and Mitchell 1977, Smith *et al.* 1977, Smith *et al.* 1978, Gouin and Link 1979).

Finally, rodents and disease may attack. Mouse damage may be eliminated by preventing their entry. The second best approach is to minimize suitable pest habitat and to trap or bait. Foliage molds are more likely to develop if the trees are in the dark or are too wet, and root rots occur if the trees have saturated, unfrozen root balls.

The purpose of this study was to (1) find suitable, inexpensive environments in which to overwinter container seedlings, (2) develop a uniform and reliable procedure to assess overwintering success, and (3) determine the cause of success or failure.

MATERIALS AND METHODS

Tree seedlings of several species of conifers and hardwoods were grown in Colorado State Styroblocks[1] in greenhouses and hardened by standard methods (Tinus and McDonald 1979) either in the greenhouse or in a lathhouse. Transfer from the greenhouse to the lathhouse was done early enough in the fall to avoid any damage to the seedlings. Seedlings to be stored in the dark over the winter were not moved into a dark location until fully hardened (Van den Driessche 1969; Johnson and Havis 1977; Tinus and McDonald 1979). For the first two winters (1977-78 and 1978-79), the seedlings were left in place until spring; then they were brought into a warm greenhouse, allowed to flush, and rated according to survival, new growth, and dieback.

During the third year (1979-80), samples of each species from each environment were brought into a warm greenhouse at monthly intervals, allowed to flush, and rated after about 6 weeks. At monthly intervals during the fourth year, samples of each species from each environment were brought into a greenhouse held just above freezing; here they were kept dormant in a nondamaging environment until the last sample was taken in mid-March. All seedlings were then allowed to flsuh together and were rated 6 weeks later.

Survival was recorded, although it is a very minimal index of success. The index commonly used in the horticultural industry is an ocular estimate of seedling vigor. Such estimation is satisfactory if one has a single diligent, well-trained observer to make all the observations. We did not. Instead we used a "recovery index" based on measurements that were reproducible with a variety of observers with a moderate amount of instruction. Original stem height minus overwinter dieback, plus new height added during flushing in the greenhouse, divided by original height, yields a dimensionless number. Zero usually means death; one means no net gain in height after one flush; numbers larger than one generally indicate satisfactory survival and growth.

For the last 2 years, thermometers were installed in the outdoor treatments to measure air temperature in the structure and root-ball temperature under the various protective covers. These were read at 8 a.m. and 3 p.m. on the same day each week from November 1 to April 1.

Each month when samples of seedlings were brought into the greenhouse, four stems of each treatment and species were cut while frozen, thawed in plastic bags, and tested for moisture stress with a pressure chamber.

Three different storage structures were used for the tests. A Quonset greenhouse covered with two layers of clear polyethylene was maintained at 1-3°C by forced air heating and cooling. Air was circulated under the benches. The seedlings were not covered in any way; they were watered as needed with a low-nitrogen nutrient solution. A second Quonset greenhouse was covered with one layer of clear plastic and one layer of milky white plastic with a light transmittance of about 25%. The containers were set on the ground. The greenhouse was completely closed, with no forced air circulation and no added heat. The third environment was a lathhouse with walls and top of snow-fence (42% barrier); the containers were set on the ground, and there was no other control of temperature or air movement.

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[1] The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Within the white plastic covered greenhouse (referred to hereafter as the white plastic house) and lathhouse, the seedlings were grouped, and each group was given one of several additional protective coverings. Each year a control group was not covered. The first year a second group was completely covered with hay, and a third group was covered with moderately dry peat. In the second year the peat covering was repeated and hay was deleted. Another group was enclosed in white plastic, and a fourth group was enclosed in white plastic suspended above the seedlings and then covered with peat. In the third year the peat covering was repeated in the white plastic house, but it was replaced by snow in the lathhouse. A third treatment at each location was not covered but was sprayed with Wiltpruf, a film-forming antitranspirant. In the fourth year the lathhouse treatments were peat cover and white plastic cover. During fall and winter, seedlings accessible to watering were kept watered as needed whenever the root balls were not frozen.

RESULTS AND DISCUSSION

Table 1 summarizes overwintering success in 1977-78 for the 11 species tested. The best environment was the greenhouse maintained above freezing where there was no opportunity for damage to be caused by low temperature or desiccation. For most species, the white plastic house was a better environment than the lathhouse. A complete covering of peat was very good, but only 4 of the 11 species were tested under peat. Peat cover was much better than hay for two reasons: hay created a favorable habitat for mice, and in spite of poisoned bait the mice heavily damaged the bur oak, crab apple, buffalo berry, and hackberry; there was no mouse damage in any other treatment. Hay also promoted molds that destroyed much of the foliage on ponderosa and Scots pine.

Species differed widely in their performance. Green ash and American elm wintered well in all environments, while ponderosa pine, Scots pine, and hackberry were very sensitive to different coverings (Table 1).

The winter of 1978-79 was very much like that of 1977-78 in terms of minimum temperatures, duration of subzero weather, and date when cold weather first came (Fig. 1). Overall, the tree species tested (Table 2) responded much the same as did those tested the first year. Peat covering in either the lathhouse or white plastic house was best, but the greenhouse was a close second. Scots pine overwintered well in all environments, but did least well with no cover or with peat plus plastic cover. Lack of cover produced poor results in both structures for all species except American plum, which did best in the lathhouse with no cover.

The four species tested appeared to be quite different in their requirements. Scots pine overwintered adequately in all environments but did best in the greenhouse or in the lathhouse covered with peat or plastic. Second best was peat or plastic covering in the white plastic house. The addition of peat over the plastic covering was detrimental, as was no cover. The same pattern occurred with green ash, but covering the plastic with peat was not detrimental; in fact, peat plus plastic covering in the white plastic house was not different from peat alone. Bur oak overwintered best under peat cover or under plastic in the white plastic house. The greenhouse was second best, on a par with peat plus plastic in the white plastic house. The oak was a total loss without cover and with plastic or peat plus plastic cover in the lathhouse. The poor performance with no cover was similar to that of the previous year. Temperature fluctuation was probably greater under the plastic cover; this negated the benefits of the higher humidity it would have created. American plum performed best in the lathhouse with no cover and second best under peat or peat plus plastic. Performance was almost as good under plastic in the

Table 1. Recovery index* ** of stock overwintered in 1977-78, based on 20 measured seedlings per species per treatment

	Species											Mean of	
Location/cover	Ponderosa pine	Scots pine	Siberian larch	Green ash	Bur oak	American elm	Cotone-aster	Siberian crab apple	Russian olive	Buffalo berry	Hackberry	11 species	4 (or 3)† species
Greenhouse	1.80 a	2.40 a	1.10 a	1.61 a	1.65 a	1.65 a	1.33 a	1.85 a	1.87 a	1.35 a	1.11 a	1.61 a	1.74 a
Lathhouse													
None	0.19 d	1.13 c	1.01 a	1.15 c	0.66 d	1.51 ab	0.77 c	0.78 c	1.18 b	0.71 c	0.46 b	0.87 c	0.75 d
Hay	0.21 d	1.14 c	0.66 c	1.37 b	††	1.03 c	1.01 b	††	0.53 d	††	††	-	(0.67)
Peat	0.75 c	1.89 b	1.05 a	-	1.05 c	-	-	-	-	-	-	-	1.19 b
White plastic house													
None	0.68 c	1.03 c	0.78 b	1.51 a	1.09 c	1.51 ab	1.29 a	2.01 a	0.78 c	0.95 b	0.42 b	1.10 b	0.89 c
Hay	1.37 b	0.39 d	0.73 bc	1.56 a	1.33 b	1.42 b	1.27 a	1.47 b	1.10 b	1.26 a	0.49 b	1.13 b	0.96 c
Peat	1.63 ab	1.74 b	1.08 a	-	1.73 a	-	-	-	-	-	-	-	1.55 a

* Recovery index = (original stem height + new growth - dieback) ÷ original height: 0 = death; 1 = no net growth after 1 flush; >1 = satisfactory survival and growth.

** Within columns, numbers followed by different letters are significantly different at the 5% level by the Duncan multiple range test.

† Included ponderosa pine, Scots pine, Siberian larch, and if available, bur oak.

†† Mouse damage prevented measuring original height and dieback.

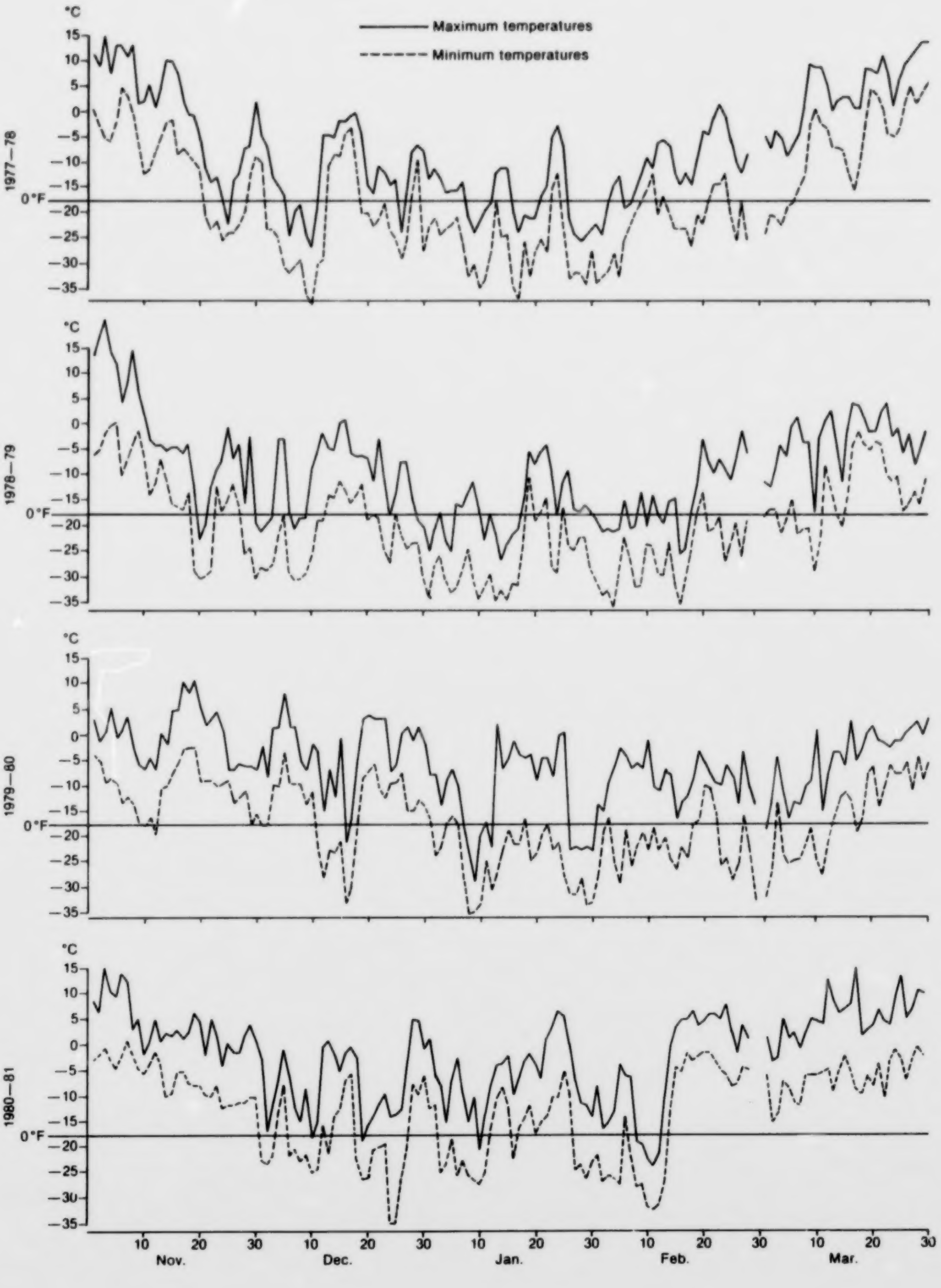

Figure 1. Daily air temperature ranges, November through March, at Bottineau, North Dakota. (A) 1977-78, (B) 1978-79, (C) 1979-80, (D) 1980-81.

Table 2. Recovery index* of stock overwintered in 1978-79, based on 30 measured seedlings per species per treatment

Location/cover	Species				Mean
	Scots pine	Green ash	Bur oak	American plum	
Greenhouse	2.71 a	1.73 cd	1.58 ab	1.08 d	1.78
Lathhouse					
None	1.94 c	1.63 de	0**	1.74 a	1.33
Peat	2.68 a	2.14 ab	1.76 a	1.48 b	2.02
White plastic	2.54 ab	1.48 e	0**	0.93 e	1.24
White plastic + peat	1.68 d	1.65 de	0**	1.43 bc	1.19
White plastic house					
None	1.40 e	1.51 e	0**	0.72†	0.91
Peat	2.29 b	2.17 a	1.70 a	1.53 b	1.92
White plastic	2.27 b	1.91 bc	1.73 a	1.32 c	1.81
White plastic + peat	1.63 d	2.32 a	1.46 b	1.56 ab	1.74

* Within columns, numbers followed by the same letter are not significantly different at the 5% level by the Duncan multiple range test.

** No survivors.

† One seedling survived.

white plastic house, but poor under plastic in the lathhouse. Performance in the greenhouse was also mediocre.

The winter of 1979-80 was milder than the previous two (Fig. 1). Minimum temperature went below -18°C (0°F) on November 21 in 1977, and on November 19 in 1978, but not until December 11 in 1979. Many more temperatures during December, January, and February of 1978-79 were above -18°C, and they went below -34°C (-30°F) only twice compared with five and six times the previous 2 years.

For ponderosa and Scots pines, the only treatments that were successful for the entire winter were snow cover in the lathhouse and peat cover in the white plastic house (Table 3). Bur oak overwintered satisfactorily in the white plastic house with peat cover or no cover, but Wiltpruf was apparently detrimental (Smith *et al.* 1977). Bur oak overwintered well in the lathhouse only when snow covered.

Unsuccessful treatments show a progressive decline in recovery index during the winter (Table 3). Large differences may indicate when the damage was done. Small differences, although statistically significant, are probably not meaningful because each month's sampling was allowed to flush at a different time in the greenhouse.

Inadvertently, another experiment was performed on Scots pine in the greenhouse. For years this species had been successfully overwintered at 1-3°C. This time the

Table 3. Recovery index* of stock overwintered in 1979-80, based on 15 measured seedlings per species per treatment per month.

Location:	Lathhouse			White plastic house		
Cover:	None	Snow	Wiltpruf	None	Peat	Wiltpruf
Month			Ponderosa pine			
Dec.	0	1.87 c	2.17 b	1.91 c	2.54 a	2.54 a
Jan.	0.13 c	1.39 b	0.11 c	1.70 a	1.90 a	1.78 a
Feb.	0	1.66 a	0	1.63 a	1.62 a	1.39 b
Mar.	0	1.32 b	0	1.37 b	1.93 a	0
Apr.	0	1.65 b	0	0	3.11 a	0
			Scots pine			
Dec.	1.68 bc	1.26 d	1.77 b	1.31 d	2.48 a	1.52 c
Jan.	1.41 b	1.12 c	0	1.36 b	1.98 a	1.27 bc
Feb.	0	1.27 a	0	0	1.26 a	1.28 a
Mar.	0	-	0	0	1.42 a	1.31 a
Apr.	0	1.35 b	0	0	3.09 a	0
			Bur oak			
Dec.	1.44 ab	1.59 a	1.27 c	1.39 bc	1.48 a	1.37 bc
Jan.	1.01 c	1.50 a	1.17 b	1.02 c	1.11 bc	1.06 c
Feb.	0	1.17 b	1.14 bc	1.04 c	1.11 bc	1.40 a
Mar.	0	1.21 a	0	1.10 a	1.15 a	0
Apr.	0	1.18 b	0	1.30 ab	1.44 a	0.32 c

* Within rows, numbers followed by the same letter are not significantly different at the 5% level by the Duncan multiple range test. Zeros indicate no survivors and were not included in the test.

greenhouse was held at -2°C, still far above the low temperature killing point of any of the tissues. The crop looked fine when it was removed from the greenhouse in the spring, but in a matter of days after field planting all of the trees turned brown and died. Inability of a frozen root ball to supply sufficient water to the shoot was undoubtedly the cause.

Temperatures in the white plastic house were generally higher, and the diurnal range greater, than in the lathhouse (Figs. 2, 3). Snow or peat cover were highly effective in raising mean root-ball temperatures and reducing root-ball temperature fluctuations. Snow or peat cover were also the most effective overwintering environments.

Moisture stress in green ash and bur oak was much higher than in ponderosa or Scots pine, but stress was not judged high enough to be lethal in any of them (Table 4). Empty xylem vessels in oak and ash may account for the high stress readings, unlike in the

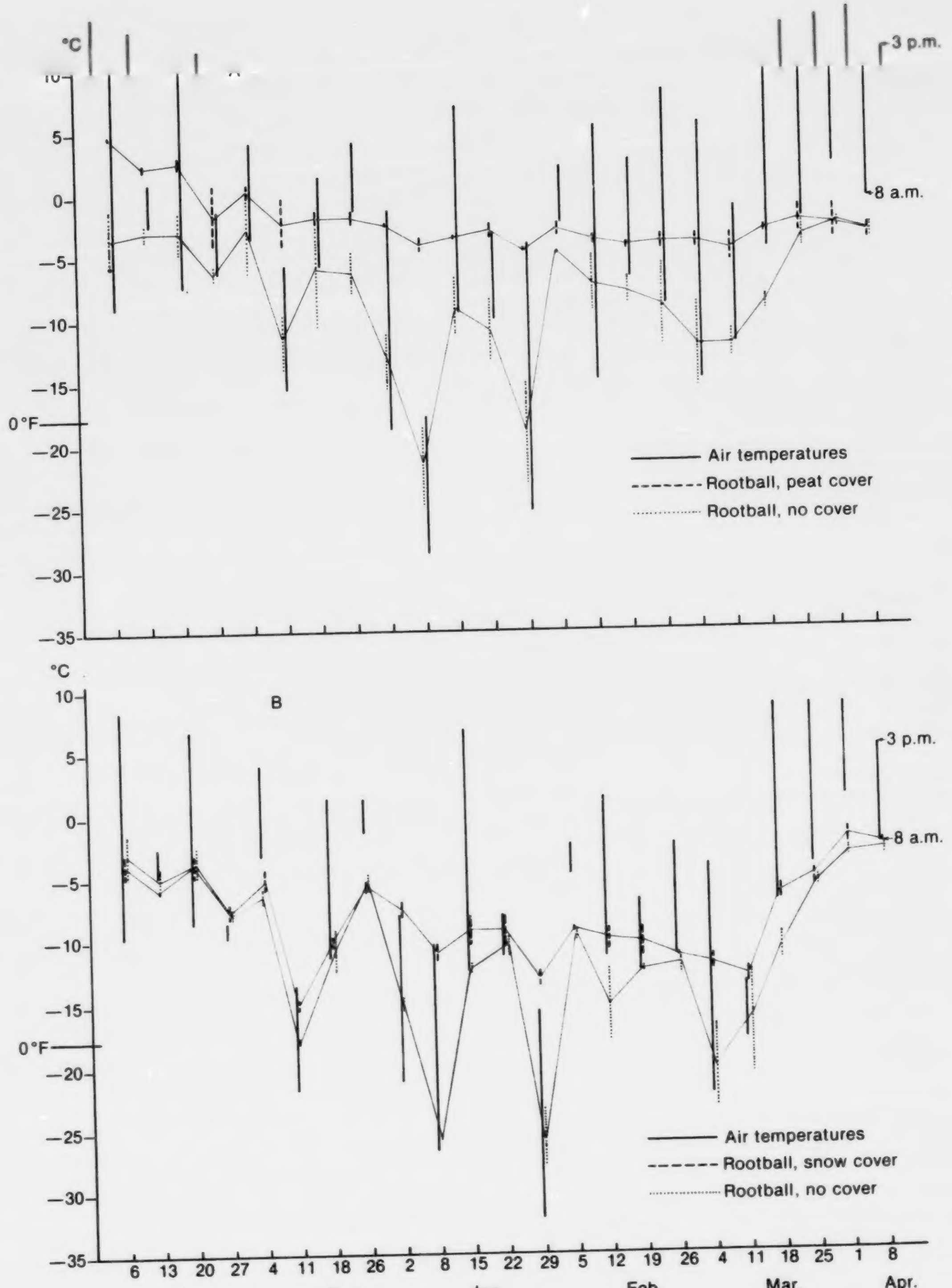

Figure 2. Daily air and root-ball temperature ranges (8 a.m. to 3 p.m.) measured at weekly intervals, November 1979 through March 1980, in the (A) white plastic house and (B) lathhouse.

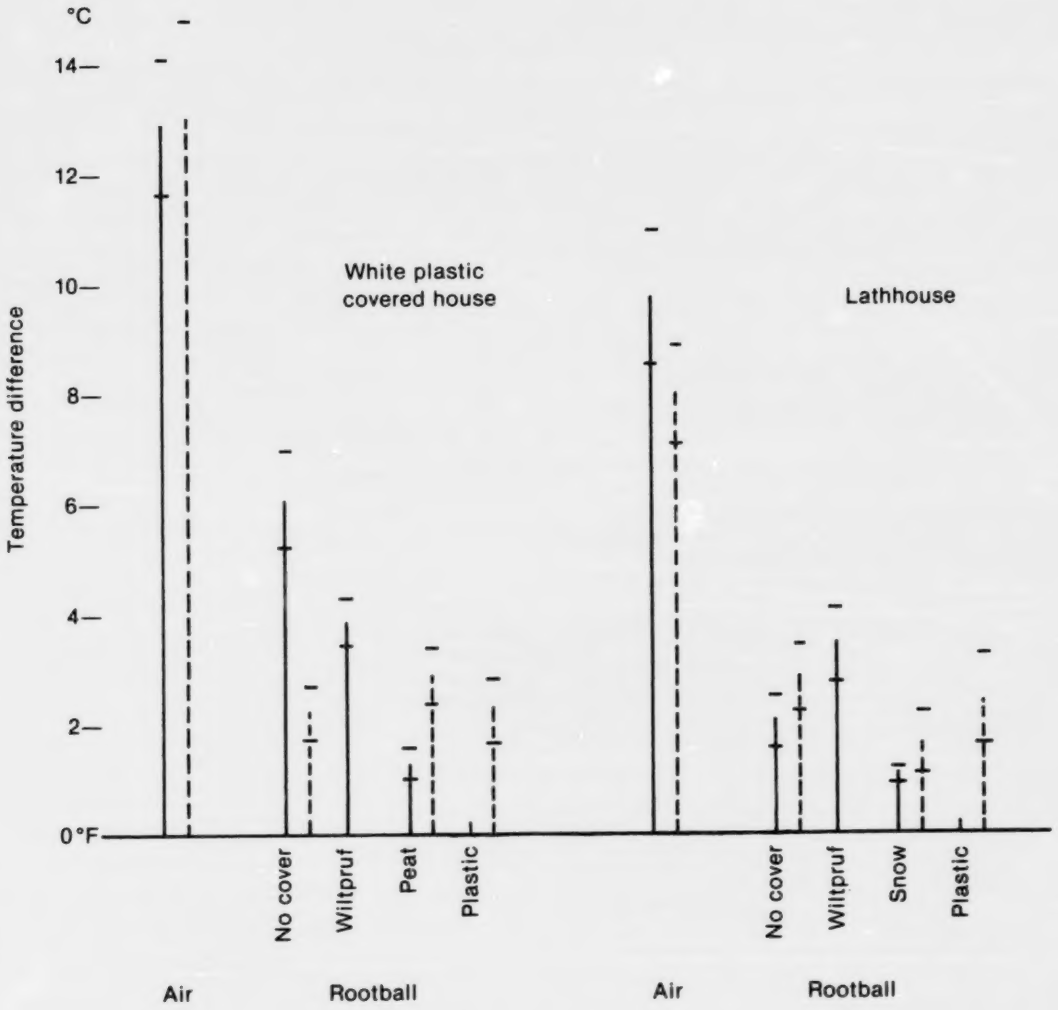

Figure 3. Mean difference between 3 p.m. and 8 a.m. air and root-ball temperatures, November through March, for the (A) white plastic house, (B) lathhouse. Solid lines are for 1979-80; dashed lines are for 1980-81. Horizontal lines represent plus and minus one standard error.

Table 4. Winter water stress (negative xylem water potential) 1979-80*

	Species			
	Ponderosa pine	Scots pine	Green ash	Bur oak
	bars			
Mean by month				
December	3.52 a	3.40 ab	1.84 c	29.51 a
January	2.54 ab	3.94 a	16.42 b	19.29 b
February	2.11 b	3.08 ab	23.38 ab	15.21 bc
March	2.62 ab	2.29 b	25.27 a	13.72 c
April	3.04 ab	2.51 b	20.03 ab	11.70 c
Mean by treatment				
White plastic house				
None	2.85 abc	3.27 ab	10.46 c	10.74 c
Peat	2.68 abc	3.76 ab	-	13.90 bc
Wiltpruf	2.86 abc	2.84 b	10.54 c	15.05 bc
Lathhouse				
None	1.51 c	1.56 c	20.97 b	24.38 a
Snow	3.04 ab	3.96 a	3.81 d	24.48 a
Wiltpruf	2.34 bc	2.38 bc	24.38 b	18.49 ab
Greenhouse	4.13 a	3.54 a	34.15 a	18.19 ab
Date x treatment interaction	NS	NS	Sig. 5%	Sig. 5%

* Within columns by month and by teatment, numbers followed by the same letter are not significantly different at the 5% level by the Duncan multiple range test. Each figure is a mean of two measurements.

pines, which have no vessels[2]. Stress in ponderosa pine was highest in December, declined, then rose again. Scots pine showed no significant trend. Stress in green ash was low in November and rose to a peak in March. Stress in bur oak declined continuously throughout the winter. There was no consistent relation between water stress and quality of overwintering environment as measured by survival and growth the following spring (Tables 3 and 4).

In addition to being even milder than 1979-80, the winter of 1980-81 had very little snow (Fig. 4). Ponderosa and Scots pines overwintered extremely well in all six environments, but did better with cover than with no cover (Table 5). Green ash overwintered well with or without cover in the white plastic house but only did well in the lathhouse without cover. Bur oak overwintered best under cover in the white

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[2] Personal communication from Merrill Kaufmann, plant physiologist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

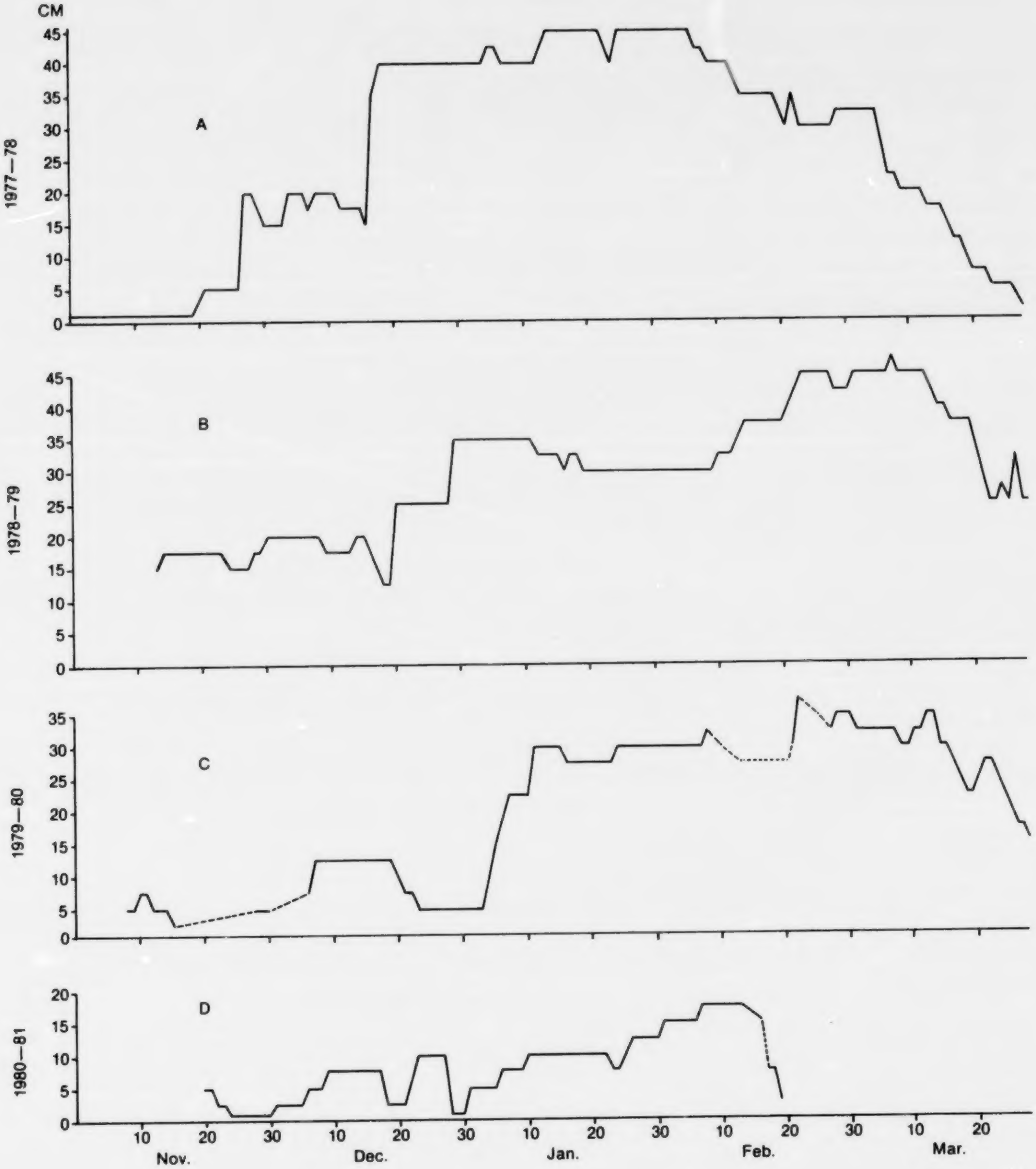

Figure 4. Daily snow cover at Bottineau, North Dakota, November through March. (A) 1977-78, (B) 1978-79, (C) 1979-80, (D) 1980-81. Dashes indicate no data available.

Table 5. Recovery index* of stock overwintered in 1980-81, based on 8 measured seedlings per species per treatment per month

	Species			
Location/cover	Ponderosa pine	Scots pine	Green ash	Bur oak
Mean by month				
November	2.73 b	3.08 a	1.71 a	-
December	2.78 b	3.44 a	-	1.05 ab
January	3.14 a	3.41 a	1.55 a	0.94 bc
February	2.92 ab	3.45 a	-	0.87 c
March	2.48 c	3.49 a	1.52 a	1.17 a
Mean by treatment				
Lathhouse				
None	2.46 d	3.08 c	1.47 a	1.09 a
Snow	2.94 ab	3.95 a	-	0.89 c
White plastic	3.05 a	3.26 bc	0.13 b	0.77 c
White plastic house				
None	2.64 cd	3.06 c	1.45 a	0.98 bc
Peat	3.05 a	3.26 bc	1.53 a	1.11 ab
White plastic	2.76 bc	3.61 ab	1.63 a	1.20 a
Date x treatment interaction	NS	NS	NS	NS

* Numbers within columns followed by the same letter are not significantly different at the 5% level by the Duncan multiple range test.

plastic house and without cover in the lathhouse. The pattern of minimum temperatures and diurnal temperature fluctuation was much the same as in the previous year (Table 6, Fig. 3). Pressure bomb measurements were more consistent than in the previous year (Table 7). For each species, water stress declined from November to a low in December or January and was followed by an increase to the November level (oak and ash) or higher (ponderosa and Scots pines). Lowest stress was under white plastic or peat in the white plastic house. Stress under other environments was somewhat higher. Although absolute stress levels varied, all four species behaved similarly with respect to environment and date. As before, the water stresses measured were not great enough to be lethal.

CONCLUSIONS AND SUMMARY

For most of the species tested, the most reliable overwintering environment is a greenhouse held just above freezing by appropriate heating and cooling. The disadvantages of this method are (1) it is more expensive than necessary and (2) in late winter, as the days lengthen and the sun's angle rises, it may become difficult to hold daytime temperatures down and the seedlings may have to be moved to another environment to prevent breaking of dormancy (Litzow and Pellett 1980).

Table 6. Minimum temperatures recorded during overwintering

Location/cover	°C 1979-80	°C 1980-81
Lathhouse		
Air	-32	-36
Root ball/none	-28	-22
Root ball/peat	-15	-22
Root ball/plastic	-	-21
White plastic house		
Air	-29	-24
Root ball/none	-25	-14
Root ball/peat	-6	-12
Root ball/plastic	-	-18

Table 7. Winter water stress* (negative xylem water potential) 1980-81

	Species: Ponderosa pine	Scots pine	Bur oak	Green ash
	bars			
Mean by month				
November	2.9 b	3.2 bc	10.7 b	7.3 a
December	2.3 b	2.0 c	4.4 c	-
January	2.5 b	1.4 c	11.0 b	2.9 b
February	3.8 ab	4.5 b	15.8 a	-
March	5.7 a	8.3 a	10.8 b	7.6 a
Mean by treatment				
White plastic house				
None	2.9 b	3.6 a	9.4 bc	3.1 b
White plastic	3.0 b	3.4 a	7.7 c	3.8 b
Peat	4.1 a	3.9 a	10.2 b	6.0 a
Lathhouse				
None	3.2 ab	4.2 a	13.4 a	6.1 a
White plastic	3.2 ab	4.2 a	11.8 ab	5.3 ab
Snow	4.1 a	4.0 a	10.8 b	7.3 a
Date x treatment interaction	NS	NS	NS	NS

* Within columns by month and treatment, numbers followed by the same letter are not significantly different at the 5% level by the Duncan multiple range test. Each figure is a mean of four measurements.

At Bottineau, however, it is quite possible to overwinter stock successfully in unheated and even open structures. Burial under snow or slightly moist peat provides an excellent and reliable environment for Scots and ponderosa pines and many of the hardwood species tested. Snow has the advantage that it leaves no residue that must be removed prior to shipment, but it is not always available when needed. If melting occurs, snow cover may result in saturated root balls and exposed tops, which are detrimental. Other covers were intermittently successful, and sometimes with hardwoods the best results were obtained with no cover.

Why this is so is still not clear. Snow and peat coverings raised minimum root-ball temperatures substantially; however, temperatures measured over the winters of 1979-80 and 1980-81 were never below the expected killing points of the species tested (Havis 1976; Studer *et al.* 1978), although the killing points of the seedlings in this experiment were not actually measured.

There was not much difference between environments in measured water stresses, none of which was high enough to be lethal (Cleary and Zaerr 1980; Heth 1980). Because there is no demonstrated correlation between water stress and subsequent survival and growth, water stress measurements would not provide the nurseryman with useful information on overwintering success.

The recovery index as defined here appears to be sensitive to the important variables in the overwintering environment, but its absolute magnitude varies with species, the degree of bud development before overwintering, and the conditions of flushing afterwards. In other words, it is a relative index of overwintering success.

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THE PAINFUL PROBLEMS OF PIONEER PROPAGATION PLANS AND OTHER ADVENTURES

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I would like to add my personal welcome to delegates here from out of the province. You'll notice a few unusual characters and peculiarities both in the people and in the place. First, trees take forever to mature, and everything can be conveniently blamed on the weather. The people are a colorful lot. We have blackhearted rednecks, who have managed to garner a few greenbacks in the pursuit of oil and politics; a strong group of Conservative blue bloods born to the purple; and some immigrants from the East--the older population regards them as white-faced, brown-nosed, yellow-bellied Orangemen! Seriously, however, we have a really cosmopolitan population and a reasonable amount of tolerance. Our Heritage Days attract tens of thousands of people to see native and ethnic displays, taste their food, watch their dances.

Looking around at what we have now, it's hard to visualize how we got to where we are in the business of reforestation and reclamation. What did we do, before tubes were in and bullets were out, when a million was a big number, and we did not know words like air pruning, outplanting, tubeling, bench spacing, and Rootrainers?

In the beginning was bare-root transplanting, along with which certain nurseries had problems with clay soil, blown weeds, and inefficient herbicides. Budgets were miniscule, and responsibility for the job of forestry research largely depended on the Canadian Forestry Service.

Those boys in green had long been trying to apply new ideas to tree growing. In 1952 a research forester from the Alberta district office, noting that scientists had discussed root growth as being independent of top growth, proposed transplanting white spruce at the Kananaskis Station over a period of 24 weeks, right up into October. Tests were replicated for 3 years, and in 1956 when this research forester, Des Crossley, became Chief Forester for St. Regis, he took along his innovative ideas.

In 1960, when John Walters first introduced the Bullet, Des, along with Larry Kennedy from the Alberta Forest Service, John Chedzoy from the Department of Agriculture, and Bob Ackerman of the Canadian Forestry Service, tried to adapt the bullet technique to Alberta conditions. They found that roots got stuck inside and would not grow into Alberta's cold soils. This was the start of most of our work, and looking back you could say our work was to suffer similarly from blind gropings into the darkness of the unknown. But note the beginning cooperation between industry, two departments of the provincial government, and our federal friends. We can applaud the fact that it is still going on today.

By 1963, new ideas were beginning to be put forward. Larry Kennedy designed a half-shell bullet that was to be held together by friction or an elastic band, and then he shopped around Edmonton for a plastics manufacturing company that could do it. John Chedzoy found, about the same time as the Ontario Forestry Service, that paper tubes impregnated with latex could be used to grow seedlings. Peat blocks such as the Jiffy 7 were tried, and then began a search for a container that would really work.

The thing that I remember most clearly from those days was the incomplete knowledge base. We would think of a solution and would have to try that solution without fully knowing its side effects. Often there would be 10 or more designs, all being tried at once. Problems would get compounded such as, for example, when unsterile cardboard tubes were tried with scorched peat that was short-fibered and everything died, or when waxed cartons were tried instead of plastic trays, and Rocky Mountain House Nursery grew a beautiful bunch of mushrooms.

Uppermost in our minds at first was the experience of the bullets, that the roots of a small seedling could not get out of the drainage hole provided and that the bullet should allow for expansion by being made in pieces. (Walter's latest design follows this idea!) Trials made by Joe Soos and company several years later showed that split bullets worked after a fashion, but the first results were not so great. As I mentioned, Larry Kennedy's design was to have the bullet open easily to let the roots out, and he thought of a two-shell unit bound with an elastic band. The idea was that the band would rot in the soil, there would be easy egress for the roots from the join all around the two halves, and it seemed like a terrific idea. We calculated that we might persuade people to plant up to 100 000 trees this way. We did not reckon with the elemental forces of nature, however. (And we grossly underestimated the eventual market.)

First, we chose a rubber band of enduring and superior quality that six years after being buried in Alberta's cold and relatively inactive soil was still there, holding the two halves of the shell together. Second, we put some lateral grooves around the sides of the shells to act as anchors for the elastic band. These indentations would turn the lateral roots as they reached the side walls, and spiralling within the container was deadly. Third, the containers were very hard to handle, with their sharp points, their tabs sticking out on each side, and their awkward shape. And fourth, the unknown factor, many of the transplants were lost because they were a bright blue. A lot of the seedlings were pulled out and broken to pieces because of the curiosity of magpies. There was one side feature that was somewhat beneficial to the effort, and that was that frost did not heave these containers out, since there was a certain amount of friction plus a locking effect caused by the lateral grooves and the rubber band.

Subsequently, in Alberta we had some doubts about tubes, thinking it would be difficult to keep the medium inside, that it would fall out when taken to the field, and so on. About 25 different ideas were tried, from square cross-sectioned bullets that were folded over to little blocks made of a foamed cement. We were not very successful. But along the way, a number of ideas showed real promise. One of our problems was bad peat, which had not been sterilized. It was thought that we should use containers and media that were sterile.

An early experimental container was the Oasis block, a foamed open-celled phenol-formaldehyde material used by florists for holding cut flowers. We took a block, cut through with a saw in both directions to form a grid of containers 3/4" x 3/4" x 3" deep. A small depression was carved with a sharp point in the tops, and a seed was placed in each and covered with a little soil. There was a little difficulty with roots moving from one block to the next, but this was thought unimportant, since a minor amount of pruning prior to transplanting might stimulate root growth even if the seedlings were shocked.

The second idea was a container made from cigarette filter material. These were 3/4" in diameter by 3-1/4" long and were prepared by being placed in a tray and watered; then the seeds were forced into the filter material.

A side note on this: the seeds could not turn over or decide which way was up. When they germinated the root would sometimes head off up into the air. The problem was solved by forming a small pocket in the top of the filter material and again covering the seed with soil.

Both ideas failed in the field. With the slightest projection of the porous or filter material to the atmosphere, the container would act as a wick, drawing all the moisture out and evaporating it, and drying out the soil for some distance around. The cigarette filter material was also particularly attractive to field mice, who used it to line their nests.

Another step forward was unconsciously taken when the roots were grown in the longitudinally directed media. It was observed that the roots would follow straight lines in the general direction of the parallel spaces between both filter fibers and long cavities in the Oasis material and did not form the usual branched pattern.

Meanwhile, urgency had been mounting for implementation of one or other of the dozens of systems tried at that time. By this I mean we were told we had to get the lead out! Public relations was one of the forces that led us into the next error. At the time, the split styrene tube was the best available plantable container. It was assumed that roots would grow out the bottom and that the roots would hold the growing medium together. The split side was to allow root pressure to force the container apart and prevent girdling.

The process was adopted and used for 5 years by both government and industry. We standardized the size of trays, and the Alberta Forest Service and North Western Pulp and Power refined the systems of filling, growing in the greenhouse, hardening-off, transporting to the planting site, and out-planting.

But, during that 5 years several of us had some concerns. Our experience with root spiralling, and the fact that in some sites the best nutrition the plants could get was in the top 3" of soil (where it was prevented from reaching the plant by the impervious styrene tube), drove us to examine ways of removing the tube before the plant went into the ground. We experimented with razor slitting, with fingers that would unfold the tube and allow the plug to drop free, or with building in a weak spot that would break. None of these ideas really worked. Styrene has a shear strength of 2000 psi, and anything we designed seemed to require several hands to operate. Bob Carman, silviculturist with St. Regis, suggested a styrofoam block with tube-size holes in it that could eliminate the trays. We decided against this partly because of tooling costs and partly because we could see extraction problems. During this time we discovered the hard way that tubes held together in a plastic tray would allow roots to mat all over the bottom, making transplanting very difficult. The solution was to paint the bottom of the tray with a copper salt chemical. While trying to make the trays less expensive, it was decided to purchase a number of foam styrene ones. Unfortunately, the solvent for the copper dissolved the tray bottoms!

In September 1970, Bob Fish, who took over from John Chedzoy, hosted a meeting of the Inland Empire forest group in Edmonton. We were all introduced to the B.C. Styroblock and the Alberta Research Council's "sausage" container. I showed the group an experimental hexagonal grid container block I had made up for the U.S. Forest Service at Bottineau, North Dakota. Following the discussions, Jim Kinghorn of the Canadian Forestry Service described the action of roots being air-pruned and the necessity for the blocks to be held up off the ground to prevent roots from jumping the distance to the ground and finding a hold. He told us that in working with bullets the Canadian Forestry Service had decided to remove seedlings from the shells and had discovered or rediscovered the principle of air pruning and its effects on root branching.

Listening to him talk, I thought that a book design, by which the seedlings could be extracted very easily, and grooves, which would direct the roots to grow quickly to the drainage holes, would be beneficial features.

We could see the potential for the idea. After discussions with people who would be the main purchasers of the new design, North Western Pulp and Power and the Alberta Forest Service, we began work for production of the original Rootrainers. We had samples under test by December and results by January. The roots really went straight and followed the grooves instead of spiralling. Patents were applied for.

We designed production tools to provide two sizes at once, for North Western Pulp and Power and for the Provincial Tree Nursery. Tooling was barely completed in time for the growing season, but tests were successful, and we were off and running.

Rootrainers went through at least 25 design changes to arrive at the present style. We at first wanted round containers, to fit dibble holes exactly. Then we found out that the planters used mattocks or spades, so we would not need to have a round container and could get better greenhouse utilization using square or rectangular ones.

The first boxes to hold the Rootrainers had no ventilation holes in the base, and we tried to depend on little knobs on the bottom of each book to hold the box up and prevent roots from growing any more. That did not work. We tried special designs to keep the books from getting out of line and finally developed corrugations that fit back to back and held the books solidly. We redesigned the shiplap seal to be one-sided instead of having to fit in pairs. We modified the lock-over ears to come up higher and thus prevent root wandering. We made a folding box so it could be shipped some distance and redesigned that several times to improve its practicality. The latest design has just been finished, and we now have developed five Rootrainer sizes, which are still not enough for the demand. Tests are being performed continually, on new materials, on new additives, on different shapes, various growing media, and so on, in available laboratories such as the Provincial Tree Nursery, the Northern Forest Research Centre, and the USDA Forest Service labs at North Dakota. Through the cooperation of these organizations we are able to solve field problems.

One problem we have been concerned with from the beginning is the filling of these small, deep containers with peat and peat and vermiculite mixes. Recently, the Provincial Tree Nursery built a shaker table that has some special characteristics. The main one is that it works very well. Vibrating horizontally with an amplitude of half an inch, the shaker table is able to settle a sticky wet mass of peat into the cavities. Operators place five trays in a holding rack and start the vibrator, and a conveyor belt brings peat to be dumped on the Rootrainers. By hand brushing, the material is spread evenly over the trays. Individual trays are then taken out and manually drop-compacted on bars in front of the shaker table, then placed back in the table for another vibratory filling. Our newest design, a modification of this has been tried out at various amplitudes and speeds and is capable of faster and more uniform filling. The prototype, sold to Simpson Timber, does a very acceptable job.

We look forward to many changes, both in design and fabrication methods. For now, however, we have a working system that pleases most people. We have turned our attention to streamlining the Rootrainer manufacturing process. Our new development is a folder-upper that will fill trays with folded Rootrainers. Many other machinery designs are on the drafting board, and we continue to see new applications for the Rootrainers system. At Spencer-Lemaire, we all enjoy the challenges.

Of course, the business that has been developed has made for a lot of traveling. One of our province's great travelers, the Honorable Horst A. Schmid, Minister of International Trade, loves to sell Rootrainers. Recently he was made an honorary chief of the Samson Band in Alberta, and because he travels so much they call him Chief Flying Eagle. Perhaps a quotation from Konrad Lorenz will be to the point:

> "How thankful I should be to Fate, if I could find but one path, which, generations after me might be trodden by fellow members of my species; and how infinitely grateful I should be, if in my life's work, I could find one small "up-current", which might lift some other scientist to a point from which he could see a little further than I do."
>
> (from King Solomon's Ring)

MAINTAINING SOIL FERTILITY IN FOREST NURSERIES IN THE PRAIRIE PROVINCES

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ABSTRACT

The six largest forest nurseries in the prairie provinces occupy a total of 358 ha and together produce 34 million bare-root seedlings annually. Soil properties vary. Most have a suitable texture and organic matter content, but most also have unsuitably high pH and salinity. Soil fertility is maintained through the application of amendments such as green manure, sphagnum peat, sand, sulfur, and sulfuric acid as well as fertilizers. It is suggested that more intensive monitoring of the seedling production system be pursued in future in order to compensate as much as possible for variation in stock quality due to weather.

INTRODUCTION

Of the six major forest nurseries in the prairie provinces, two (Pine Ridge and Oliver) are located in Alberta, three (Prince Albert, Big River, and Indian Head) are located in Saskatchewan, and one (Pineland) is located in Manitoba. Although they are distributed in a northwest-southeast band across the provinces (1600 km from Pine Ridge in the northwest to Pineland in the southeast), their climate is similar. Mean annual precipitation ranges from 375 mm at Pineland to 470 mm at Oliver in the northwest (Table 1). There is even less variation in the length of the frost-free period: Pine Ridge is lowest with 106 days[1] and Indian Head is highest with 130 days.

SIZE AND PRODUCTION OF NURSERIES

The nurseries differ widely in size and production (Table 2). In total, they currently use 358 ha to produce 34 million bare-root seedlings which, with the exception of Oliver and Indian Head, is comprised of conifers entirely. Pine Ridge produces lodgepole pine and white spruce, Prince Albert and Big River produce jack pine and white spruce, and Pineland produces jack pine, white spruce, red pine, and Scots pine. The *raison d'etre* of Oliver and Indian Head is to produce stock for shelterbelt and recreational plantings and as such produce deciduous trees and shrubs (e.g., elm, willow, poplar, caragana, etc.) predominantly but lesser amounts of Colorado spruce, white spruce, and Scots pine. Because of wider spacing requirements for deciduous stock, both nurseries have relatively large areas in current use compared to the number of seedlings produced.

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[1] The nursery is only 3 years old, and this value represents the mean length recorded during 1978-80.

Table 1. Mean annual precipitation and length of frost-free period at selected prairie nurseries

Nursery	Province	Mean annual precipitation mm	Frost-free period days
Pine Ridge	Alberta	415	106
Oliver	Alberta	470	122
Prince Albert	Saskatchewan	390	112
Big River	Saskatchewan	400	110
Indian Head	Saskatchewan	380	130
Pineland	Manitoba	375	115

Table 2. Currently producing area and annual bare-root seedling production in selected prairie nurseries

Nursery	Province	Area currently used ha*	Production millions	Conifers as fraction of production %
Pine Ridge	Alberta	73	10.0	100
Oliver	Alberta	65	3.2	30
Prince Albert	Saskatchewan	61	8.0	100
Big River	Saskatchewan	13	4.0	100
Indian Head	Saskatchewan	142	6.0	7
Pineland	Manitoba	4	2.5	100
Total		358	33.7	

* 1 hectare = 2.5 acres.

SOIL CHARACTERISTICS

Soil characteristics at the nurseries vary throughout the region (Table 3), and certain chemical characteristics are closely associated with texture. Pineland is sandy, Pine Ridge and Prince Albert are loamy sand, Big River and Indian Head are sandy loam, and Oliver is mostly clay. Available water capacity (AWC)[2] varied from 8.5% at Pine Ridge to 26.5% at Big River and was related to the amount of silt-sized particles in the soil. Thus although Big River and Indian Head are nominally similar in soil texture (sandy loam), their percentages of silt are 31% and 18%, respectively, and this is reflected in the AWC. Soil pH is acceptable at Pine Ridge only; the level at all other nurseries is too high. (Recommended standards are given in Table 5.) Moreover, while calcareous subsoil exists in parts of these nurseries, free carbonate is present in the surface soil at Indian Head.

Electrical conductivity (EC) is a measure of total salinity, and only Pineland nursery is sufficiently low in soluble salts to be of no concern. Calcium and magnesium are the predominant water-soluble cations at all nurseries except Oliver, where sodium predominates. Among water-soluble anions, sulfate is present in highest concentration at all nurseries, particularly Prince Albert and Oliver (60 and 450 ppm, respectively). Chloride level at Indian Head (75 ppm) is about twice the concentration at other nurseries. Organic matter content is similar at all nurseries except at Indian Head, where the level is approximately one-half that of the others.

Total nitrogen (N) at Oliver nursery (0.14%) is twice the level at other nurseries and this gives it the lowest carbon:nitrogen ratio (9.6) of the six nurseries. The next higher C/N ratio is at the Indian Head nursery (11.6), but the remainder vary between 15 and 20. A low C/N ratio (e.g., less than 12:1) indicates that less nitrogen will be immobilized during breakdown of soil organic matter and therefore more of it will be available to plants through nitrification. Nitrate nitrogen (NO_3-N) is a measure of readily available nitrogen in the soil. Pine Ridge and Big River contain greatest amounts (81-83 kg/ha), whereas Pineland is least (19 kg/ha). The phosphorous[3] level at Indian Head (240 kg/ha) was more than 2-4 times the concentration determined in other soils. Oliver and Indian Head are highest in ammonium acetate-extractable potassium (995 and 1494 kg/ha) and reflect the naturally high K levels in medium and fine-textured prairie soils. Overall, Pineland soils are lowest in fertility, which is due undoubtedly to the sand texture. Cation exchange capacity (CEC) reflects texture as well as organic matter content. At Oliver, CEC is two to three times that at the other nurseries and is due to the high clay content (70%) of this soil.

MAINTENANCE OF SOIL FERTILITY

Organic Amendments

The maintenance of soil fertility in prairie forest nurseries is through application of green manure, peat, sand, sulfur, and sulfuric acid and, of course, fertilizers (Table 4).

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[2] Available water capacity is the difference between soil moisture content at 0.1 bar tension and soil moisture content at 15 bars tension.

[3] Determined by extraction with 0.5 M sodium bicarbonate and development of color with ascorbic acid.

Table 3. Summary of soil characteristics at selected tree nurseries in the prairie provinces

Nursery	Province	Texture	AWC[1] %	pH	EC[2] mS/cm	OM[3] %	Total N %	NO_3-N kg/ha	P kg/ha	K kg/ha	CEC[4] meq/100 g
Pine Ridge	Alberta	LS	8.5	5.3	0.92	6.0	0.23	83	87	390	12.34
Oliver	Alberta	C	24.9	6.5	1.48	6.8	0.41	36	53	995	44.22
Prince Albert	Saskatchewan	LS	21.6	6.8	1.65	6.5	0.22	42	91	306	20.96
Big River	Saskatchewan	SL	26.5	6.3	1.27	6.1	0.19	81	74	293	17.62
Indian Head	Saskatchewan	SL	16.8	7.9	1.30	3.4	0.17	58	240	1494	15.29
Pineland	Manitoba	S	16.1	6.7	0.34	5.6	0.16	19	98	136	15.84

[1] AWC = available water capacity.

[2] EC = electrical conductivity.

[3] OM = organic matter.

[4] CEC = cation exchange capacity.

Table 4. Amendments used in soil fertility program

Nursery	Province	Amendments				
		Green manure	Peat	Sand	Sulfur	Fertilizer
Pine Ridge	Alberta	X	X		X	X
Oliver	Alberta	X	X	X		X
Prince Albert	Saskatchewan	X	X		X	X
Big River	Saskatchewan	X	X		X	X
Indian Head	Saskatchewan	X				X
Pineland	Manitoba		X		X	X

The objectives of green manuring and the application of peat are to maintain an adequate level of organic matter (approximately 5%), since organic matter adds fiber, improves tilth, and most important in coarse-textured soils) increases cation exchange capacity and available water capacity. At Pine Ridge, green manuring consists of plowing under fall rye and faba bean, whereas at Oliver, Prince Albert, and Big River, fall rye and oats are used. At Indian Head, the crops used are crested wheatgrass, alfalfa, and oats. No green manure is used at Pineland nursery. Peat is a common source of organic matter at all nurseries in the region; it is generally spread to a thickness of 5-10 cm and plowed into the soil during preparation of the seedbed. Because of its relative accessibility and low cost at most prairie nurseries, it is anticipated that peat will continue to play a significant role in their management. At Indian Head, laboratory studies to determine the breakdown rate of peat have shown that 40% of the original peat remains in the soil after 4 years. Such studies at other nurseries would be helpful in utilizing this organic amendment more judiciously. At Pineland nursery, sawdust has been used as a substitute for peat, and although it was an effective source of organic matter, nitrogen chlorosis developed in succeeding crops of seedlings unless extra nitrogen was applied to compensate for that assimilated by microorganisms.

Inorganic Amendments

Sand has been used at Oliver and Indian Head to modify the fine-textured soil in the seedbeds. On the whole, this method of modifying texture has been impractical because of the large amount of sand required. Moreover, at Indian Head its use on coniferous species was discontinued because the sand supply was a source of calcium carbonate. Elemental sulfur is used to acidify the soils and thus reduce their pH to levels that are more suitable for conifers. Sulfur is recommended for this role because, although it is slow-acting (up to 2 years), it is recognized that coarse- and medium-textured soils generally have a low buffering capacity and therefore slow pH changes are preferable. The usual recommendation for S is 550-1100 kg/ha. At Pine Ridge and Prince Albert, soil pH is reduced to suitable levels through acidification of the irrigation water with sulfuric acid. The water is reduced from its initial pH of about 8.0 to pH 5.5 or 6.0. The acid is injected automatically into the irrigation system following monitoring of the initial pH.

Fertilizers

Without exception, the nurseries use fertilizers to maintain soil fertility. At Pine Ridge, most of it is applied as a solution via injection into the irrigation system, and the amount added through the season is based on accumulated degree-days. The liquid fertilizer applied is 28-10-22. Solid fertilizer as either ammonium sulfate (21-0-0) or urea (46-0-0) is used to supplement this when irrigation is inappropriate. The other nurseries use solid fertilizers exclusively, the only difference among them being the type and amount of fertilizer. For example, Oliver uses 46-0-0, monoammonium phosphate (11-48-0), and potash (0-0-62), whereas Prince Albert and Big River apply ammonium nitrate (34-0-0), 21-0-0, 11-48-0, and 0-0-62. Pineland, on the other hand, uses ammonium phosphate (16-20-0), 34-0-0, ordinary superphosphate (0-20-0), and potassium sulfate (0-0-50). For its conifers, Indian Head applies only nitrogen (30 kg/ha as 34-0-0) since phosphorus and potassium levels are already adequate (Table 3). The total amount of fertilizer applied depends on the age of the crop, but basically phosphorus and potassium are applied and mixed into the seedbed prior to seeding, while nitrogen is top-dressed in multiple (3-5) applications during the growing season to achieve the prescribed levels (Table 5). In the case of nitrogen, 56, 112, and 112 kg/ha may be required for 1-0, 2-0, and 3-0 stock, respectively.

Table 5. Recommended standards for forest nursery soils in the prairie provinces

Texture	LS-SL
pH	5.5
EC	<0.75 mS/cm
OM	5 %
NO_3-N	56-112 kg/ha
P	45-90 kg/ha
K	280 kg/ha

The type of fertilizer is selected on the basis of local conditions, availability of material, and demonstrated effect. For example, it was found at Indian Head that Colorado spruce and Scots pine grew equally well when nitrogen was supplied as either ammonium or nitrate. At Prince Albert it was found that, whereas jack pine benefited equally from either source of nitrogen, white spruce favored the ammonium form. As a result of the alkalinity of most of the soils, 21-0-0 and/or 16-20-0 are recommended because of their high residual acidity. They help to lower soil pH to the recommended level (Table 5). If, on the other hand, adjustment of soil pH is not desired, then 34-0-0 is used. Local conditions also dictate the choice of the potassium fertilizer. Where salinity is a potential problem, 0-0-50 is preferable to 0-0-62 because of the lower salt index of the former material.

RECOMMENDED STANDARDS

The recommended standards (Table 5) are intended as guidelines for the nurseries. Site selection initially may influence all the listed characteristics, but unsuitable texture will definitely have profound consequences on the entire nursery as a viable operation. Whereas the other characteristics can be manipulated with relative ease, textural changes are often impractical and uneconomical because of seedling costs. While these standards are recommended (based on plot experiments), each nurseryman is urged to determine the specific requirements for stock of prescribed quality at his particular location. Production of bare-root stock is subject to numerous vagaries of the weather. Whenever possible, the reproducible aspects of the operation should be maintained and strengthened.

CONCLUSIONS

1. Different soil characteristics at prairie forest nurseries have resulted in different approaches to maintenance of soil fertility. Each nurseryman should be familiar with the limitations of his particular situation and take appropriate steps to deal with these problems specifically.

2. More 'maintenance' studies are needed. The Indian Head study on the breakdown of peat should be pursued at other locations, since it would enable a more efficient use of this resource. The long-term effect of sulfate (from elemental sulfur and sulfuric acid) should be monitored. Also, where facilities permit, integration of foliar analysis into the nursery should be considered.

3. More judicious use of fertilizers and irrigation would undoubtedly increase efficiency of the nurseries generally. With desired standards of nursery stock already in mind, manipulation of these inputs should be done (while monitoring nutrient leaching) to see how the stock is affected. On the prairies, however, input of heat units will remain a critical determinant of crop quality.

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IRRIGATION REGIMES IN A BARE-ROOT NURSERY

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"Irrigation is an important nursery management tool for modifying the seedling environment and influencing seedling behavior" (Cleary *et al.* 1978). Adequate irrigation is essential to maintain sufficient water in plants. Soil moisture supply and atmospheric demand play important roles in limiting the water supply available to the plants. The basic purpose of irrigation is to uniformly distribute water with a minimum of waste, while producing a succcessful, economical crop.

I believe that in the past, and to some extent even now, some nursery managers used more irrigation than was needed to produce stock. Too much water can produce stock that is morphologically and physiologically unable to survive early fall frosts in the nursery. They will also be unable to maintain vigor during refrigerated storage periods and may not survive and grow on droughty planting sites similar to the steep, shallow, soiled slopes that face south and west in southern Oregon. The application of too little water produces its own problems. Seedlings can be droughted-stressed in the nursery to a point where the shoot and root mass is reduced and/or the plant is damaged or killed.

The best irrigation regime for any given nursery cannot, and should not, be extrapolated and used in its pure form at another nursery. The type of soil, time of year, climatic conditions, species of seedlings, seedling size specifications, and stage of stock development must be evaluated before and during the establishment of an irrigation regime. As stock specifications and nursery cultural techniques are altered, it will be necessary to modify the scheduling and amount of irrigation applied. To determine the "best" irrigation regime, you may use the following system.

I. Determine irrigation demands

    A. Irrigation needed to enhance germination of tree seed

    B. Irrigation needed to control soil temperatures after germination

    C. Irrigation needed for plant growth to meet stock specifications, both shoot and root

    D. Irrigation needed to compensate for losses from evaporation and/or evapotranspiration

    E. Availability of water, amount, and timing (some have irrigation district water)

    F. Climatic conditions
        1. Temperature
            a. High (heat damage)
            b. Low (frost damage)
            c. Diurnal fluctuations (cooler nights may result in heavier dew, which results in better recovery from day's moisture losses)

2. Wind speed (consider when windy and calm periods occur)
    a. Calm (less than 6 mph)
    b. Windy (more than 6 mph)
3. Humidity
    a. High (requires less evapotranspirative cooling)
    b. Low (increases solar intensity and requires more evapotranspiration by the plant)

G. Determine growth periods for different species (plants require more water during active growing periods)

H. Soil type (this can profoundly affect plant's ability to take up water, storage capacity, penetration rate)

I. Irrigation needed to accomplish cultural practices
1. Pesticide applications--incorporation in soil
    a. Fungicides (control of root rotting organisms)
    b. Herbicides (pre-emergents)
    c. Insecticides (control of soil-borne insects)
2. Fertilizer applications
    a. Flush fertilizer from foliage
    b. Incorporate into soil
    c. Distribute fertilizer through irrigation system
3. Root pruning, plowing, disking, and root wrenching
4. Development and breakdown of cover crop
5. Facilitation of hand weeding
6. Prepare soil for sowing, fumigation, and lifting

II. Determine monitoring method to ensure adequacy of irrigation. To accomplish this it will be necessary to research different monitoring methods and determine the applicability to your situation.

A. Gravimetric: Oven drying--most basic and most accurate of all methods. System is used to calibrate other methods.

B. Neutron Probes: This system is quick and accurate and can be economical. Some agricultural crop growers report a 50% reduction in the amount of water used. Others report increases in yield; sometimes more water was needed to obtain these increases.

C. Electrical Resistance Methods: Gypsum blocks--accuracy is hard to maintain, problems are great.

D. Visual and Tactile (see and touch) Method: Does not give quantitative results, but may be needed at such times as post-sowing for seed germination.

E. Tensiometers: Easy to operate, accurate in lower tension ranges, and excellent when high soil moisture levels (near field capacity) are maintained. When soil is dried to induce dormancy, units lose tension and are inaccurate.

F. Pressure Chambers: A quick, foolproof method of measuring plant water potential in seedlings. Readings should be taken pre-dawn. Plants recover at night but must have adequate moisture to permit recovery.

G. Computers: This is a method of monitoring that is really coming on. There are groups in Idaho and California that offer irrigation sheduling services.

H. Temperature of Crop Canopy: A concept that measures the temperature of the foliage and relates that temperature to the temperature of surrounding air. The theory is that when soil moisture levels are reduced below the plant's needs, the plant becomes stressed and its temperature rises.

After 3 full years of operation, we are using an irrigation regime that utilizes the pressure chamber and the visual and tactile techniques. We are also testing a heat sensing device and evaluating a neutron probe. The neutron probe that we are using can also determine soil compaction. We have conducted limited tests to monitor compaction created during the turning under of the cover crop. An example of the irrigation regime we use is:

2-0, 3-0, and Transplants

Prior to Irrigation Scheduling by PMS

2 hours three times per week

This schedule should be adjusted to keep soil moisture at or near field capacity. Soil samples should be taken randomly throughout the area twice weekly.

Irrigation Scheduling by PMS

June 1 - July 15: Irrigate when average pre-dawn PMS reaches 5 bars.

July 16 - October 1 (or beginning of fall rains): irrigate when average pre-dawn PMS reaches 10 bars.

All irrigation for PMS relief should be as early in the morning as possible to provide immediate relief and to take advantage of lower evaporation rates and to alleviate poor distribution patterns caused by later day winds. Duration of irrigation should be 2 hours, but a longer period may be necessary to wet the soil profile and reduce the incidence of moisture-related soil compaction.

Irrigation for Cooling

Because more water will be available to the seedlings this season, a need for cooling irrigation is not anticipated. Should stock conditions indicate a need for cooling, guidelines will be issued at that time.

1-0 Stock

After sowing and until germination is complete, keep the soil surface moist to prevent buildup of surface crust. This may require two, three, or four irrigation periods a day. Generally, irrigating for one-half hour is sufficient, but when the wind speed exceeds 5 or 6 mph, 45 to 60 minutes may be needed to provide adequate coverage over all areas.

Douglas-fir and True Firs

After germination is complete, irrigation for cooling should provide all the water necessary, but soil samples should be taken twice weekly to ensure that the soil profile is moist through the rooting depth (6-12") and that moisture related soil compaction is not occuring; if necessary, additional irrigation will be scheduled.

Cooling irrigation is done according to the following schedule:

Soil Surface Temperature	Period
35°C	6/1-6/14
36°C	6/15-6/30
38°C	7/1-7/14
40°C	7/15-7/31
43°C	8/1-8/14
46°C	8/15-end of season

Irrigation Period

Thirty minutes when wind speed is 6 mph and below, 45-60 minutes when wind speed is above 6 mph. Note that as the seedlings grow they are able to withstand higher soil surface temperatures and therefore we irrigate at increasing higher temperatures through the growing season.

Pines and Cedars

After germination is complete, irrigate according to the following schedules:

Lodgepole, Sugar, Western White, Ponderosa Pine, and Cedars

To August 15 - 1.5 hours daily in the early morning
August 16 to end of season - 2 hours twice weekly

Irrigation schedule should be adjusted to maintain a proper level of soil moisture and to prevent moisture-related soil compaction. No irrigation for cooling is planned for the pines and cedars.

I encourage all of you to monitor new technology. It is too easy to become locked into a given regime when there may be more efficient ways to obtain desired results.

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IRRIGATION WATER QUALITY IN TREE NURSERIES IN THE INLAND WEST

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INTRODUCTION

Irrigation water quality is the most critical factor in tree nursery management. Even soil properties are secondary to water quality because poor irrigation water can ruin nursery soil.

The definition of water quality is dependent on use, but for agricultural purposes the concentration and composition of dissolved salts determine its value for irrigation (USDA Salinity Lab 1969). In semiarid climates, where evaporation exceeds precipitation, the soluble salt levels of irrigation water often reach damaging levels. Most of the Inland West is classified as semiarid, especially at lower elevations where most tree nurseries are located.

All plants are susceptible to salt injury under certain conditions; but tree seedlings, and conifers in particular, are very sensitive to soluble salts. Many bare-root tree nurseries in the Inland West have experienced growth problems that can be attributed to soil salinity. Salinity problems can develop in containerized seedling nurseries when irrigation and fertilization are improperly applied.

The objective of this study was to chemically analyze irrigation water from a variety of tree nurseries in the Inland West and to discuss techniques to remedy water quality problems.

SURVEY AND CHEMICAL ANALYSIS

Water samples were collected from 11 forest nurseries in eight western states; two nurseries supplied samples from two different sources (Table 1). The samples were sent in clean plastic bottles to Denver where they were stored under refrigeration (36-38°F) to minimize chemical changes during storage.

Once all 15 samples had been received, they were taken to Agricultural Consultants Laboratory in Brighton, Colorado, for testing. A batch analysis was performed, which reduced the chances for variation due to analytical technique. The complete chemical analysis consisted of total salts as measured by electrical conductivity, pH, and specific ion concentrations of sodium (Na^+), calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^+), carbonate (CO_3^{--}), bicarbonate (HCO_3^-), sulfate (SO_4^{--}), chloride (Cl^-), nitrate (NO_3^-), and boron (BO_2), all measured in milliequivalents per litre (California Fertilizer Association 1975).

Two indices of water quality were computed from ion concentrations upon completion of the chemical analyses: adjusted sodium adsorption ratio and residual sodium carbonate (California Fertilizer Association 1975).

Table 1. Salinity hazard

Recommended levels of electrical conductivity (mcmhos/cm)[1]:

Low	<250
Medium	250-750
High	750-2250
Very high	>2250

Nursery	Location	Electrical conductivity (mcmhos/cm)	Rating
Nevada State	Washoe Valley, NV	328	Medium
Nevada State	Tule Springs, NV	368	Medium
Utah State	Draper, UT	265	Medium
Mt. Sopris	Carbondale, CO	397	Medium
Colorado State	Ft. Collins, CO		
	1. College Lake	281	Medium
	2. Greenhouse	58	Low
Albuquerque	Albuquerque, NM		
	1. Reservoir #2	204	Low
	2. Well #2	261	Medium
Mountain Valley	Lincoln, NM	1005	High
Towner	Towner, ND	745	Medium
Lincoln-Oakes	Oakes, ND	675	Medium
Lincoln-Oakes	Bismarck, ND	1460	High
Big Sioux	Watertown, SD	577	Medium
Bessey	Halsey, NE	115	Low
Oklahoma State	Norman, OK	861	High

[1] Page 80 in USDA Salinity Lab. (1969).

WATER QUALITY TEST RESULTS

Soluble salts can injure plants in four ways: 1) reduce moisture availability, 2) decrease soil permeability, 3) cause direct toxicity, and 4) alter nutrient availability (Fuller and Halderman 1975).

1. Salinity Effects on Water Availability

The total concentration of dissolved salts in irrigation water is generally expressed as electrical conductivity, which is measured in units of conductance (micromhos/cm) at a standard temperature (25°C). Dissolved salts decrease the free energy of water molecules and reduce water availability to plants. This osmotic inhibition is a function of total salts irrespective of the specific ions.

The salinity hazard has been divided into four ratings based on observed effects on plant growth (Table 1). Most of the nurseries tested in the medium salinity category, with three each in the high and low classes. None of the irrigation water samples exceeded 2250 mcmhos/cm (the very high category), which has been given as the upper limit for successful agriculture (USDA Salinity Lab 1969).

2. Decrease Soil Permeability

Water quality can also reduce plant growth indirectly through its effects on soil permeability that occurs as a result of the chemical properties on the sodium ion. High sodium ion concentrations reduce the mutual attraction of soil particles, which causes them to disperse and destroys beneficial soil structure. The resultant loss in pore space restricts air and water movement within the soil profile. This phenomenon is cumulative because as soil permeability is decreased, less leaching occurs and more sodium ions are trapped in the root zone.

In assessing the sodium hazard, the ratio of sodium to calcium and magnesium ions is more significant than the actual sodium concentration because calcium and magnesium ions increase soil structure. These beneficial ions cause soil particles to attract, and the resultant flocculation increases soil porosity and permeability.

The relative proportion of sodium to other beneficial ions can be calculated in several ways. The "adjusted sodium adsorption ratio" (ASAR) was developed to include the effect of carbonate and bicarbonate ions on the ratio of sodium to calcium and magnesium (Ayers 1977). Carbonates can dissolve or precipitate calcium from soil solids and thus affect the sodium ratio.

Residual sodium carbonate (RSC) is another index of the deleterious effects of sodium on soil permeability. Sodium carbonate can dissolve soil organic matter, further destroying soil structure. RSC is computed by subtracting the sum of calcium and magnesium ions from the sum of the carbonate and bicarbonate ions in the solution (Christiansen *et al*. 1977).

The recommended levels for the ASAR and RSC are provided in Table 2 along with the test values for the nursery water samples. Only two nurseries had values exceeding the "good" category, which indicates that calcium and magnesium salts usually predominate over sodium in nursery irrigation waters in the Inland West.

Table 2. Soil permeability

Recommended levels:

	Good	Marginal	Poor
Adjusted sodium adsorption ratio (ASAR)[1]	<6.0	6.0-9.0	>9.0
Residual sodium carbonate (RSC)[2]	<1.25	1.25-2.50	>2.50

Nursery	Location	ASAR	RSC	Rating
Nevada State	Washoe Valley, NV	7.8	2.4	Marginal
Nevada State	Tule Springs, NV	0.9	0.0	Good
Utah State	Draper, UT	1.0	0.0	Good
Mt. Sopris	Carbondale, CO	0.2	0.0	Good
Colorado State	Ft. Collins, CO			
	1. College Lake	0.6	0.0	Good
	2. Greenhouse	0.1	0.0	Good
Albuquerque	Albuquerque, NM			
	1. Reservoir #3	1.3	0.3	Good
	2. Well #2	1.4	0.3	Good
Mountain Valley	Lincoln, NM	1.4	0.0	Good
Towner	Towner, ND	0.1	0.0	Good
Lincoln-Oakes	Oakes, ND	1.0	0.0	Good
Lincoln-Oakes	Bismarck, ND	15.7	3.8	Poor
Big Sioux	Watertown, SD	0.5	0.0	Good
Bessey	Halsey, NE	0.5	0.1	Good
Oklahoma State	Norman, OK	1.7	0.2	Good

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[1] Pages 135-150 in Ayers (1977).

[2] Page 81 in USDA Salinity Lab. (1969).

Ironically, irrigation water can be too pure for proper seedling culture. Water low in dissolved salts can leach too much calcium from the soil, destroying soil structure and causing water penetration problems. An irrigation water source with approximately 1 milliequivalent (20 ppm) of calcium has been given as the minimum acceptable level (California Fertilizer Association 1975). In this survey, only the Colorado State Nursery greenhouse water falls in this category, which should not be a problem because additional calcium is injected as fertilizer.

3. Direct Ion Toxicity

Three ions have been observed to injure plant tissue directly: sodium, chloride, and boron. Sodium and chloride can be absorbed either through the foliage or by the root system. Foliage injury is particularly severe under sprinkler irrigation systems. In general, trees and other woody perennials are sensitive to rather low concentrations of sodium and chloride compared to annual crops (Ayers 1977). Boron toxicity is hard to predict because the range between beneficial and toxic concentrations is narrow for some plants (Doneen 1975).

Only three of the irrigation waters tested in this study exceeded the safe level for toxic ions (Table 3). The Nevada State Nursery at Washoe Valley tested marginal for both sodium and boron. The Lincoln-Oakes Nursery at Bismarck had a marginal rating for boron but poor rating for sodium. The irrigation water for the Oklahoma State Nursery barely reached the marginal boron category. None of the nursery water samples had excessive ratings for chloride.

4. Alter Nutrient Availability

Saline irrigation water can change the availability and utilization of plant nutrients. This effect is particularly difficult to define because of the complicated chemical interactions in soil chemistry and seedling physiology. Excess soil calcium can chemically immobilize phosphorus in the soil and inhibit plant uptake. Iron chlorosis is a complex nutritional disease of woody plants and has been associated with an abnormal accumulation of salt ions in conifer seedling foliage (Carter 1980).

CORRECTIVE TREATMENTS

Irrigation water quality is rarely the sole cause of salinity problems but rather is one in a series of interacting conditions. Other factors such as the soil drainage, irrigation method, cultural practices, climatic conditions, and crop salt tolerance are equally important (Christiansen *et al.* 1977). A nursery manager must consider all these factors before designing an irrigation program. This becomes increasingly more important as water salinity increases.

1. Bare-root Nurseries

There is no economical way to treat saline irrigation water. Removal of salt ions with an ion exchange system is effective but very expensive. Water with high sodium but low total salt levels can be treated with gypsum ($CaSO_4$) to improve its infiltration rate (Doneen 1975), but none of the nurseries in this survey has this type of water.

Table 3. Direct ion toxicity

Recommended levels[1]:

Foliar adsorption	Good	Marginal*	Poor**
Sodium (meq/L)	<3.0	<3.0	-
Chloride (meq/L)	<3.0	<3.0	-
Root adsorption			
Sodium--adjusted sodium adsorption ratio (ASAR)	<3.0	3.0-9.0	>9.0
Chloride (meq/L)	<4.0	4.0-10.0	>10.0
Boron (mg/L)	<0.5	0.5-2.0	>2.0

Nursery	Location	Sodium (meq/L)	Sodium ASAR	Chloride (meq/L)	Boron (mg/L)
Nevada State	Washoe Valley, NV	3.5	7.8*	0.2	1.2*
Nevada State	Tule Springs, NV	0.5	0.9	0.1	0.3
Utah State	Draper, UT	0.7	1.0	0.5	0.1
Mt. Sopris	Carbondale, CO	0.1	0.2	0.0	0.0
Colorado State	Ft. Collins, CO				
	1. College Lake	0.4	0.6	0.1	0.0
	2. Greenhouse	0.2	0.1	0.0	0.0
Albuquerque	Albuquerque, NM				
	1. Reservoir #2	0.9	1.3	0.2	0.0
	2. Well #2	0.9	1.4	0.2	0.0
Mountain Valley	Lincoln, NM	1.4	1.4	1.2	0.1
Towner	Towner, ND	0.1	0.1	0.1	0.1
Lincoln-Oakes	Oakes, ND	0.8	1.0	0.3	0.2
Lincoln-Oakes	Bismark, ND	10.9	15.7**	1.3	1.4*
Big Sioux	Watertown, SD	0.4	0.5	0.2	0.0
Bessey	Halsey, NE	0.3	0.5	0.0	0.0
Oklahoma State	Norman, OK	1.4	1.7	0.2	0.5*

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[1] Pages 135-150 in Ayers (1977).

Acidification of irrigation water to lower pH or improve soil infiltration rate has been accomplished by a variety of techniques. Acidification with sulfuric acid can be effective with irrigation waters containing residual sodium carbonate but is expensive, dangerous, and corrosive to irrigation equipment (Doneen 1975).

Leaching to remove excess salts from the root zone and to prevent their accumulation is the only true treatment for saline irrigation water. Chemical soil amendments with gypsum will help increase soil permeability when sodium is the predominant salt. Soils dominated by calcium can be treated with sulfur to convert insoluble calcium carbonate to the more soluble calcium sulfate form. Organic matter additions can increase soil structure and resultant porosity. Cultural practices such as deep ripping to fracture impermeable soil layers and the installation of tile drains to increase subsurface drainage have proven effective. Irrigation techniques such as applying enough water to completely saturate the soil profile and scheduling irrigation during low evaporation periods can prevent salt accumulation (Carter 1975).

2. Containerized Nurseries

Container seedling systems offer many advantages for managing irrigation water quality. Container seedlings are a higher value crop, which makes some treatments more economical, and greenhouses offer considerably more environmental control.

Although salt ion removal is still uneconomical for irrigation water, many container seedling operations acidify water to lower pH. One of the advantages of growing seedlings in containers is the ability to formulate the container potting mix for maximum permeability. Vermiculite, perlite, styrofoam beads, and other coarse materials are used to generate pore space in the rooting medium.

There are also some inherent dangers in container seedling production that relate to irrigation water quality. Because of the large amounts of irrigation water used in most greenhouses, there is a real potential for salt accumulation in the potting soil. This danger is amplified when nutrients are injected into irrigation water, because fertilizer salts add to the total salinity level. The only solution is to ensure that excess salts are leached from the potting soil during each irrigation by watering until leachage drains out the bottom of the container.

CONCLUSIONS

Irrigation water quality in tree nurseries is a function of four factors. High levels of dissolved salts can osmotically inhibit plant water uptake. The relative proportion of sodium to other ions in irrigation water can affect soil permeability. High levels of sodium, chloride, and boron can cause direct toxicity to plants through either foliage or root absorption. High calcium concentrations in the root zone can induce nutrient deficiencies by chemical inhibition of normal ion uptake and metabolism.

The best control for saline water problems is to avoid them in the first place by a comprehensive examination of water quality. Water treatments such as de-ionization are uneconomical, although gypsum or sulfuric acid amendments are sometimes used to stimulate infiltration rates. The only true solutions to saline water problems are improving and maintaining good soil structure and irrigating properly so that harmful salts are leached from the root zone.

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HERBICIDE INVESTIGATIONS IN CONIFEROUS TREE NURSERIES IN SASKATCHEWAN AND ALBERTA

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In this paper I will provide a brief overview of the current research in weed control for the production of conifer seedlings and transplants in Alberta and Saskatchewan. Replicated weed control trials are being conducted at the PFRA. Tree Nursery, Indian Head, Saskatchewan; Alberta Tree Nursery (ATN) and Horticultural Centre (HC), Edmonton; and Pine Ridge Forest Nursery (PRFN), Smoky Lake, Alberta, although informal experimentation is occurring at other nurseries too. The overall objectives of the Indian Head and Edmonton trials are to reduce hand weeding to a minimum without jeopardizing crop safety or incurring phytotoxic soil residuals in subsequent crops. At Pine Ridge the major objective is similar, but more emphasis is being placed on herbicides as a standby procedure in the event of emergencies or if nonchemical methods would be too costly.

Before I review the investigations now under way, I will briefly outline what weed control practices are being used in the production of bare-root conifer seedlings.

CURRENT PRACTICES

Prior to seeding conifers, the nurseries at Indian Head and Prince Albert, Saskatchewan, fumigate the seedbeds with dazomet, which is sold as Mylone or Basamid. Seedbeds are generally treated in September for spring seeding.

At Prince Albert, diphenamid is applied after seeding and prior to hydromulching. Enide is applied at 11.2 kg/ha; no residual effects have been observed on succeeding cover crops. There is, however, a trend to using glyphosate at 1.1 kg a.i./ha for both white spruce and jack pine at any stage of growth (S. Price, personal communication). Glyphosate is also used at Indian Head for weed control in Colorado spruce seedbeds.

At the Pine Ridge Forest Nursery, neither fumigants nor herbicides are used in general production of coniferous seedlings. At the Alberta Tree Nursery, linuron and cyprazine are used in conifer transplants, but seedlings are started in the greenhouse.

HERBICIDE INVESTIGATIONS

The weeds of major concern (Table 1) are quite similar for all the nurseries in this discussion, although narrow-leafed hawk's beard appears to be confined to the two Alberta nurseries. Also, since PFRN is at a relatively new and isolated site, it does not have all the weed problems other nurseries do.

In this discussion, I will review some of the results achieved with various candidate herbicides.

Table 1. Major weed species of Alberta and Saskatchewan tree nurseries

Common name	Scientific name
Common groundsel	*Senecio vulgaris*
Purslane	*Portulaca oleracea*
Stinkweed	*Thalspi arvense*
Flixweed	*Descurainia sophia*
Lamb's-quarters	*Chenopodium album*
Redroot pigweed	*Amaranthus retroflexus*
Narrow leafed hawk's-beard	*Crepis tectorum*
Russian pigweed	*Axyris amaranthoides*
Scentless chamomile	*Matricaria maritima*
Dandelion	*Taraxacum officinale*
Perennial sow thistle	*Sonchus arvensis*
Canada thistle	*Cirsium arvense*

GLYPHOSATE–ROUNDUP

Until about 5 years ago, the only overall postemergent treatment available for conifer production was Varsol or herbicidal oil. As a result, if the soil fumigant or preemergence herbicide was not effective, there was basically no alternative but to resort to expensive hand-weeding.

Glyphosate has changed this picture, although it is not registered for use as an overall spray in conifers. Glyphosate has been widely tested on Colorado spruce, as outlined in Table 2. This species as 2-0, 2-1, 2-2, and 2-3 stock has been subjected to overall glyphosate treatments from 1.0 to 2.8 kg/ha as single and repeated treatments during May, when in full flush, to August (Carter 1978; Carter *et al.* 1978; Howe and Morgan 1977). In four reports, glyphosate from 1.0 to 1.7 kg/ha applied at any time during the growing season, repeated up to three times per year, did not cause any crop injury. Glyphosate at 2.2 kg/ha, however, did cause severe injury to 2-0 seedlings and at 2.8 kg/ha caused some injury to transplanted Colorado spruce in 1 year.

White spruce transplants were tolerant to glyphosate at 1.5 to 1.7 kg/ha when treated in August, but treatment in May or June occasionally caused damage (Table 3). New sowings showed poor tolerance in one trial at Pine Ridge Forest Nursery, but 2-0 were tolerant to single applications. When the rate of glyphosate was increased to 2.2 or 2.8 kg/ha, white spruce tolerance was reduced in 2-2 stock and particularly so in 2-0 stock.

Scots pine was considerably more sensitive to glyphosate than Colorado spruce and white spruce when treated in May (Table 4). Since only a few reports are available for applications in July and August, further testing of low rates at these later stages appears worthwhile.

From other studies, pine appears to be more tolerant to glyphosate when treated at the mature growth stage. This is supported in basic research work by Lund-

Table 2. Effects of glyphosate applied on Colorado spruce seedlings and transplants at various growth stages

	Age of Colorado spruce	Time of application	Effect on Colorado spruce
A. Glyphosate at 1.0 to 1.7 kg/ha			
PFRA-77	2-2	May, June, July single, double, triple (s, d, t)	Neither survival nor growth affected
PFRA-78	2-2 2-3	May, June, July s, d, t	No injury
PFRA-79 Prod. scale	2-1	June, July, August	No injury
PFRA-79 Prod. scale	2-2	July, August	No injury
ATN and HC[1]	2-1	August	No injury
PFRA-78	2-0	May, June, July s, d, t	No injury
PFRA-79 Prod. Scale	2-0	May, June, August August	No injury
B. Glyphosate at 2.2 to 2.8 kg/ha			
PFRA-77	2-2	May, June, July s, d, t	No injury
PFRA-78	2-2	May, June, July s, d, t	Slight tip burn, growth not affected
PFRA-78	2-0	May, June, July s, d, t	Severe injury, significant growth reduction

[1] From Grainger (1980).

Table 3. Effects of glyphosate applied on white spruce seedlings and transplants at various growth stages

	Age of white spruce	Time of application	Effect on white spruce
A. Glyphosate at 1.0 to 1.7 kg/ha			
PFRA-77	2-2	May, June, July	June application caused reduced growth
PFRA-78	2-2	May, June, July	May application--slight tip burn, growth not affected
ATN and HC[1]	2-2	August	No injury
PFRN-80	1-0	July	Poor tolerance
PFRN-80	2-0	July	Good tolerance
PFRA-78	2-0	May, June, July	Good tolerance to single application, double and triple application caused injury
B. Glyphoste at 2.2 to 2.8 kg/ha			
PFRA-77	2-2	May, June, July single, double, triple, (s, d, t)	Poor tolerance, reduced growth
PFRA-78	2-2	May, June, July s, d, t	May and June--tip burn, growth not affected
PFRA-78	2-0	May, June, July	May--marginal tolerance, severe injury from double and triple applications

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[1] From Grainger (1980).

Table 4. Effects of glyphosate on pine seedlings and transplants

	Age	Species	Rate and time of application	Effects on pine
PFRA-77	2-2	Scots pine	1.7 kg/ha, May	Injury, plants recovered
PFRA-77	2-2	Scots pine	2.8 kg/ha, May	Significant growth reduction
PFRA-78	2-0	Scots pine	1.1 kg/ha May	Injury, survival not affected
PFRA-78	2-0	Scots pine	2.2 kg/ha, May	Significant growth reduction, survival not affected
PFRN-80	1-0	Lodgepole pine	0.6, 1.1 kg/ha, July	Severe injury
PFRN-80	2-0	Lodgepole pine	0.6, 1.1 kg/ha, July	Good tolerance

Hoie in Norway (Lund-Hoie 1976). He found that Norway spruce absorbed four to five times more of the glyphosate in plants at the shoot growth stage than in plants that had ceased growth. Norway spruce had the capacity to rapidly detoxify the absorbed glyphosate.

A third factor was that glyphosate when absorbed was translocated only over short distances.

OXYFLUORFEN—GOAL

Oxyfluorfen or Goal 2E has registration in the U.S. for preemergence and postemergence weed control in conifer seedbeds, transplants, and container stock. In Canada, Goal is available for experimental testing only. This chemical has been tested at the Alberta Tree Nursery and Horticultural Centre in Edmonton, Pine Ridge Forest Nursery at Smoky Lake, and at the PFRA Tree Nursery, Indian Head, Saskatchewan.

At Smoky Lake, Goal at 1 and 1.9 kg a.i./ha caused some injury to white spruce when applied in May, but no injury was noticed when treated in July. Goal provided excellent weed control at these rates (D. Altmann, personal communication).

At the federal agricultural research station at Morden, Manitoba, oxyfluorfen at 1.5, 3, and 6 kg/ha was applied to Colorado spruce about 25 cm in height on April 22, prior to weed growth and bud break. In this replicated trial no injury to spruce was noted and weed control was good.

At Indian Head (Alspach and Neill 1980a, b), oxyfluorfen was applied pre- and postemergence to sowings of Colorado spruce and Scots pine. Postemergence applications of oxyfluorfen caused significant injury to both species, but the preemergence treatment appeared safe. Alspach and Neill reported excellent weed control from these treatments.

The effectiveness of oxyfluorfen for weed control has also been confirmed in trials with woody ornamentals at two locations in Alberta.

Although this chemical is not commercially available in Canada, Goal has considerable potential as a preemergence treatment in spruce and pine seedlings.

BIFENOX-MODOWN

Bifenox, commercially known as Modown, was applied at 2.2 and 3.4 kg/ha for both pre- and postemergence in Colorado spruce and Scots pine sowings at Indian Head (Alspach and Neill 1980a, b; Carter 1978). As a preemergence, bifenox caused stem twisting in both species. Both pre- and postemergence applications of bifenox provided excellent weed control (mainly shepherd's-purse and purslane).

Bifenox is a herbicide in the substituted diphenyl ether class, and its activity is not significantly affected by soil organic matter content and soil types. Like other preemergence herbicides it requires some moisture after application for activation. Bifenox has low water solubility and relatively short persistence (half-life in soil of 7-14 days). Oxyfluorfen is a more active herbicide than bifenox and is more persistent.

CONTROL OF GRASSY WEEDS

This year we are testing two experimental herbicides for postemergence control of grassy weeds at ATN and HC, Edmonton. These chemicals are sethoxydim (formerly BAS 9052), commercially known as Poast, and fluazifop methyl (formerly TF 1169), commercially known as Fusilade. Both were combined with a surfactant. Poast and Fusilade were both applied at 0.2, 0.4, and 0.8 kg/ha on June 1 to white spruce and lodgepole pine. Neither species showed any injury as a result of these treatments. In this trial, grassy weeds were not present for evaluation, but in vegetable trials at Brooks we have shown that these chemicals will control volunteer cereals, wild oats, barnyard grass, and green foxtail at 0.4 kg a.i./ha.

Another postemergent herbicide, diclofop methyl, commercially known as Hoe Grass, has also been evaluated at several locations. Hoe Grass appears safe to use on conifer seedlings; however, its control spectrum is more limited than those previously mentioned.

Fusilade and Poast should be tested again to confirm their safety to coniferous species at several growth stages and also to evaluate their efficacy in controlling perennial grasses such as quack grass and brome grass.

In similar work, we are also evaluating bromoxynil and bentazon as directed sprays for control of common groundsel and weeds of the mustard family. Crop tolerance is not a problem as a directed spray, and work from P.E.I. indicates that bromoxynil can be applied overtop of white spruce seedlings without detrimental effect.

SUMMARY

Herbicidal treatments are being developed at several nurseries in Alberta and Saskatchewan for the production of conifer seedlings. Of these treatments, glyphosate as an overall application has probably the greatest potential, but further investigations are still required for pine seedlings. Two diphenyl ether herbicides, bifenox and oxyfluorfen, have shown encouraging results and have the advantage that their activity is not significantly affected by soil organic matter content. However, neither Goal nor Modown is currently commercially available.

New herbicides are also being developed for special weed problems such as grassy weeds. This research effort should result in more alternatives for controlling a wide spectrum of weeds and for special situation problems in conifer nurseries.

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INTRODUCTION

From the establishment of the first nursery in 1896 to 1956 the sowing of tree seed was by hand at all the Ontario nurseries. This was a slow but very efficient use of tree seed by the highly competent persons used for this purpose.

The expansion of reforestation in the postwar years and the replacement of horses with tractors brought about a search for the high-capacity, inefficient seed drill adapted from agriculture to meet the demand for the annually increasing seedbed areas at the 10 provincial nurseries. The range of seeders varied from the Gandy to the highly recommended Oyjord seeder of today in the constant search to cut down the waste of tree seed with these mechanical dispensers, which require two to nine viable seeds for every shippable seedling.

The first operational vacuum seeder to make its appearance in Ontario, and possibly in Canada, was a crude design put together by two Canadians of Japanese origin in the late 50s or early 60s near the town of Chatham. This seeder eliminated the labor required to thin and space mechanically drilled sugar beets and turnips by spacing the seed with the aid of a household vacuum running off the 12-volt system of the tractor.

The next vacuum seeder was built by E.O. Nyborg (Nyborg 1972) in 1970 at the University of British Columbia in connection with the "Kinghorn Blocks" containers. It is now produced by the Vancouver Bio-Machines Systems Ltd.

It was Nyborg's invention and the Vancouver Bio-Machines Systems Ltd. that enabled us to produce the first prototype precision vacuum seeder and the subsequent operational model.

OBJECTIVES AND REQUIREMENTS OF NURSERY SEEDERS

The ultimate objective of each nurseryman is the production of a tree seedling from each viable seed sown. Unfortunately, even in the controlled environment of a greenhouse, the best we could achieve at the Swastika Nursery from 1964 to 1972 was a shippable tree from 2% to 6% below viability for jack pine and the two spruces. This situation cannot be repeated out-of-doors, where three viable seeds are required to produce a living tree, since both the seed and the seedling are at the mercy of the elements. Nurseries (Brown 1973) with a partially controlled environment should therefore be able to produce a better ratio of seedlings per viable seed by making better use of the available tree seed through the use of a precision seeder.

On April 26, 1979 we provided Vancouver Bio-Machines Systems Ltd., with a sketch and the following information concerning our requirements:

1. The vacuum cylinder would have to be 42 inches between the first and the last seed drop, with a spacing of 4 inches between the rows, for a total of 10 rows per bed.

2. The linear drop would have to be 1.5 inches between seed to give us 20 seeds per square foot and, it was hoped, 18 shippable trees (Armson and Sedreika 1979).
3. The seeder would have to be preceeded by a soil packing drum and the seeder would have to be supported on low-pressure tires because we sow our soil on raised beds.
4. The seeder would have to be enclosed to protect both the seed and the vacuum cylinder from dust.
5. The seed drop from the vacuum cylinder to the soil surface would have to be 1 inch, with a drill depth of 0.25 inch for a total of 1.25 inches.

THE PROTOTYPE

The seeder we received was an adaptation of the Vancouver Bio-Machines head attached to a carrying frame that resembled the Oyjord seeder.

The machine was P.T.O. driven for both the vacuum pump and the compressor. After a few modifications to these items, we tested and demonstrated the seeder at our Dryden Nursery from June to September 1979 and compared its peformance against the Oyjord and the Dryden hybrid.

Some of our findings and observations were as follows:

1. The seeding device would deposit a single seed 98% of the time, as stated by the manufacturer.
2. The depth of the drills could not be maintained at the desired 0.25 inch due to their independent suspension.
3. The drills would pick up any wood fiber in our high-organic soil and drag it and the seed along with it, as indicated by the clumping of the germinants.
4. Due to the 42-inch height of the seed drop, much of the seed would bounce right out of the drill grooves subsequently welded to the packing drum instead of 0.25-inch drills on our first trial.
5. During the second trials, we decided to mulch our seed with

   (a) nursery soil,
   (b) peat, and
   (c) beach sand, to control the seed covering more precisely. Beach sand proved to be the most stable covering, with nursery soil next, and peat soil the least stable.

6. Finally, we sowed all of our jack pine with the vacuum seeder in the spring of 1979 for the 1982 planting season, with a 40% chance of attaining our 18 to 22 trees per square foot because of the aforementioned problems.

THE PRODUCTION MODEL

After the 1979 trials we were convinced that our objective of reducing the ratio of viable seed per shippable seedling could be met after further modifications to the seeder. We therefore decided to build the seeder to our original specifications by salvaging those parts that we could use from the prototype and manufacturing those that we required locally.

1. The first item of consideration was the replacement of belt and pulleys on the compressor and the vacuum with hydraulic motors.
2. We next built the frame to our original specifications along with the vacuum cylinder.
3. We decreased the lateral spacing from 4 to 2 inches, thus increasing the number of rows on the bed from 10 to 20.
4. We can also reduce the linear spacing between the seeds from 1.50 to 0.50 inch to adjust for viability and to allow the seedlings to support each other linearly in a solid row, since widely-spaced seeds were hammered into the ground by heavy rain drops.
5. The angle iron on the packer and in front of each seed drop was reduced from 1.0 to 0.75 inch for better depth control.
6. The seed covering would be sand to a depth of 0.25 inch or less, applied with the Swastika sander.
7. After sanding, the bed would be gently rolled with a smooth packer.

OPERATION OF THE SEEDER

Anyone familiar with the Vancouver Bio-Machines Systems Ltd. seeder can operate the nursery seeder.

1. The vacuum pump has a minimum capacity of 40 c.f.m. per minute at 0 pounds of mercury and 10.8 c.f.m. at 20 pounds of mercury. We have discovered that 31.5 c.f.m. at 4.5 pounds of mercury will hold the seed on the vacuum cylinder.
2. The compressor has a displacement of 15.4 c.f.m. at 0 pounds and 7.4 c.f.m. at 90 p.s.i. Our requirement to operate the air brush, the seed release, and the vacuum purge systems is 11 c.f.m. at 20 p.s.i.
3. The sequence of operations consists of (a) the vacuum-operated seed pickup, (b) a compressor-operated air brush to limit the pickup to a single seed, (c) a compressed-air seed drop, and (d) the compressed-air vacuum hole purge or cleaner.

CONCLUSIONS

We have tested the production model of the precision seeder and are satisfied that it will help us attain our original objectives at least in part by:

1. reducing the tree seed required to grow a shippable seedling,
2. adjusting the linear seed drop to compensate for seed viability, thus enabling us to produce close to the desired density of 18 to 22 trees per square foot,
3. eliminating the thinning and spacing of seedling stock, and

4. facilitating better use of small and improved seed lots through the elimination of waste seed.

ACKNOWLEDGMENTS

The advice, encouragement, and assistance of the following people was greatly appreciated:

1. G. Shikaze, Vancouver Bio-Machines Systems Ltd., for the production of the prototype seeder,
2. J.M. King, for the background information of the original seeder,
3. T. Poulin, the Dryden Nursery Mechanic, for putting together the production model, and
4. the rest of the Dryden Nursery staff for the testing and operation of the seeders.

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MONITORING GROWTH PROGRESSION THROUGH ROOT COLLAR DIAMETER MEASUREMENTS

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ABSTRACT

Four years of root collar diameter growth progression monitoring of 1+2 (1½+1½) and 3+0 black spruce (*Picea mariana* (Mill.) B.S.P.), 2+2 and 3+0 white spruce (*Picea glauca* (Moench) Voss), and 2+0 jack pine (*Pinus banksianna* (Lamb.)) are analyzed and discussed. The modified Weibull function provided excellent correlation coefficients for transplant stock (r^2 = 0.973 to 0.942) and for seedbed stock (r^2 = 0.916 to 0.881).

The application of these regression curves to the forecasting of stock size and quality is possible only while monitoring the growing season and noting the fluctuating properties of root collar diameter.

INTRODUCTION

The production of morphologically uniform nursery stock in any one year and from year to year is essential to the determination of desired stock types of plantation establishment. Variation between years may result in the planting of morphologically undesirable nursery stock or stock of poor physiological quality. To ensure superior morphological quality, growth progressions through the growing season must be understood. To effect necessary changes, we must have an understanding of where we should be with respect to growth at all times. By identifying inherent growth patterns of the various stock types produced in any nursery, we will be able to change cultural practices in order to modify the growth pattern to achieve the desired outcome. To this end, growth progession monitoring was undertaken at the Thunder Bay Forest Station. Root collar diameter (RCD) was used as the attribute of growth increment because of the limited variation and the smaller sample size required.

METHOD

Growth progression monitoring was carried out following the guidelines provided by the Ontario Ministry of Natural Resources in "Quality control procedures for nursery stock production."

RESULTS

Analysis of the data was performed using linear and modified Weibull functions. The RCD growth progressions were returned to the origin to enable us to analyze the growth pattern of the present year regardless of the preceding years.

The modified Weibull formula was superior in fit (r^2) to the linear function because of its ability to accommodate a slow spring start and a gradual tapering off to completion at the end of the growing season. Only the modified Weibull function will be discussed here.

The modified Weibull function formulaes all had excellent correlation coefficients (Table 1). Transplant stock was more uniform than seedling stock within and between years due to density, available moisture, and variation in cultural practices.

In the transplants, PIm 1+2 and PIg 2+2, variation was minimal over the first 100 days of the growing season. From then on variation increased, with the result that total growth (Table 2) varied from year to year. Measurements taken in April, May, or June would be the basis for any changes in cultural plans. The uniformity of growth at this time and the erratic nature of growth later in the season would make monitoring early in the year profitable for locating the origin, but the adjustment of plans would be questionable. Variation in the growth rate does not occur until July. At this time it is usually too late to effect any change.

The seedbed stock, PIm 3+0, PIg 3+0, and PNb 2+0, exhibited variation from the onset of growth. This may be explained by the variety of densities under which the stock was grown. Seedbed stock also showed growth reductions that appear to have been caused by climatic conditions.

The RCD in the seedbed stock increased and decreased erratically following weather patterns. In periods of hot, dry days, RCD decreased and then increased when wet weather returned. The transplant growth progressions were affected similarly, athough no reductions took place.

DISCUSSION

Root collar diameter is affected by xylem pressure potential (Hinckley *et al.* 1974). On days in which xylem pressure reached 25 bars, the diameter upon rehydration was less than that prior to dehydration. During periods of severe drought, as experienced in the spring of 1980, diameters of all species displayed a decrease or slowing in growth. Daytime temperatures in excess of 30°C and relative humidity of less than 20% for an extended period were responsible for poor correlation. Height growth and presumably dry weight increases were occurring at this time, but RCD measurements were not indicating this. When an extended spring drought occurs, common in our region every 4 or 5 years, the RCD measurements are relatively difficult to assess and the alteration of the cultural operation plan is impractical since we are not certain of the actual growth progression (dry weight).

Nursery practices dictate that irrigation and nitrogen be reduced in August to induce dormancy and bud set. This leaves a period from May 1 to July 31 to change the cultural plan for the purpose of increasing growth. When a spring drought of 4 to 6 weeks negates the monitoring of growth progressions, there is little chance of successfully altering the growth to the desired outcome in the remaining time.

CONCLUSIONS

The use of RCD measurements for growth progression is impractical in regions such as ours, where extended periods of drought render them uninterpretable. Data

Table 1. Weibull function curves r^2 values for five stock types

Species	Age	Weibull formula	r^2
bS	1+2	$Y = 3.20\ (1-e^{6.524.06\ x^{2.574}})$	0.973
bS	3+0	$Y = 3.00\ (1-e^{1.401.04\ x^{1.799}})$	0.881
wS	2+2	$Y = 2.81\ (1-e^{1.712.07\ x^{3.380}})$	0.942
wS	3+0	$Y = 2.30\ (1-e^{2.693.05\ x^{2.285}})$	0.916
jP	2+0	$Y = 2.21\ (1-e^{5.615.06\ x^{2.557}})$	0.911

Table 2. Total growth for each year for five stock types

Stock type	Total growth (mm)				
	bS 1+2	bS 3+0	wS 2+2	sW 3+0	jP 2+0
1977	3.08	1.60	2.40	-	-
1978	2.67	2.29	2.80	2.10	2.05
1979	3.08	2.45	2.80	2.15	2.20
1980	2.72	2.45	-	1.70	1.20

Table 3. Production of density monitored seedbed stock

Stock type	Density (m^2)		
	bS 3+0	wS 3+0	jP 2+0
1977	368.1	-	-
1978	143.1	152.7	292.2
1979	267.4	33.3	309.6
1980	294.6	303.4	364.3
Desired	432.0	432.0	372.0

collected thus far will be beneficial in years when droughts do not occur. The curves, however, must not be taken literally but a gray area of plus or minus 10% of the curve must be observed before making any alterations.

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EVALUATING ROOT REGENERATION POTENTIAL OF BARE-ROOT NURSERY STOCK

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ABSTRACT

The terms Root Regenerating Potential (RRP) and Root Growth Capacity are reviewed to overcome current confusion in the literature. It is suggested that the term Root Regenerating Potential be used exclusively to describe the potential of transplanted or outplanted nursery stock root systems to initiate or elongate new white roots shortly after transplanting or outplanting.

The literature on RRP is reviewed with respect to the development of the methodology used to evaluate this important physiological attribute of nursery stock. The review of literature includes the work done at the Faculty of Forestry at the University of Toronto and at the School of Forestry at Lakehead University during the last decade. The review also includes the initial work done by Dr. E.C. Stone and his associates in California.

The physiological quality and RRP work now in progress at the School of Forestry at Lakehead University is described and the methods used to bioassay the nursery stock are listed: 1) the pot bioassay method; 2) bioassay in the root mist chamber; and 3) bioassay in the root growth box.

INTRODUCTION

The terms Root Regenerating Potential (RRP) and/or Root Growth Capacity (RGP) are not clearly or concisely defined in spite of their extensive use in describing the post-planting root behavior of nursery stock.

According to the Concise Oxford English Dictionary (Sykes 1976) the word *potential* means 'capable of coming into being or action' and *capacity* means 'power of containing or producing'. As both RRP and RGP are usually measured by the number, length, area, volume, or weight of the roots produced by nursery stock after transplanting or outplanting, it seems that the two terms are *almost* identical in meaning. As Root Regenerating Potential was the first term used by Stone and his co-workers (Stone and Schubert 1956, 1959a) and as new roots are not 'contained' within the old root system but 'come into being' from it, *the term Root Regenerating Potential is recommended.* The following definition of Root Regenerating Potential is proposed:

> The potential of transplanted or outplanted nursery stock root systems to initiate or elongate new white roots shortly after transplanting or outplanting.

The following notes will assist the reader in interpreting the definition.

1. The term Root Regenerating Potential is to be preferred over all other terms used to describe the potential to grow or growth of seedling roots shortly after transplanting or outplanting.

2. Root Regenerating Potential is usually measured in one or several of the following units. These may be encoded for rapid subjective estimates.

A. Root Number (RN)

The number of new white root buds or tips produced in a given post-transplanting or post-outplanting period.

B. Root Elongation (RE)

The total length of new white root buds or tips produced or elongated during a given post-transplanting or post-outplanting period.

Note: In both A and B above, the new white root buds or tips may be classified according to:

a. their size (i.e., Small = <2.0 mm (buds), Medium = 2.1 mm to 1.0 cm, and Large = >1.0 cm)

b. their location in terms of
   i) the order of roots on which they occur (i.e., first order (tap root), second and third (principal lateral roots), fourth, fifth, order roots, etc.)
   ii) the position and condition of their points of occurrence (i.e., end or cut end, side or wounded side).

C. Root Area Index (RAI)

The change in Root Area Index (Morrison and Armson 1968) of the entire root system from immediately before transplanting or outplanting to the end of a given post-transplanting or post-outplanting period.

D. Root Volume (RV)

The change in Root Volume (Iyer-not dated; Burdett 1979a, b) of the entire root system from immediately before transplanting or outplanting to the end of a given post-transplanting or post-outplanting period.

Note: In both C and D above it is important to realize that *new roots may or may not be regenerated or elongated and old roots may or may not be sloughed off* during the post-transplanting or post-outplanting period. Thus the differences between initial RAI or RV (x-values) and final RAI or RV (y-values) will be the result of the elongation and sloughing off of roots during the period. The following examples illustrate some of these events:

a. RAI or RV normally increases when roots are elongated if none or few of the roots are sloughed off the old root system.

b. RAI or RV may remain constant when new roots are elongated if old roots are sloughed off at an equal rate.

c. RAI or RV may decrease when roots are elongated if old roots are sloughed off at a faster rate.

d. RAI or RV usually decreases when no new roots are elongated and old roots are sloughed off.

3. The post-transplanting or post-outplanting period for root growth in root regeneration studies should be defined in days. As the periods allocated for root regeneration range from 7 days (Burdett 1977) to 40 days (Day and MacGillivray 1975) or more and vary with species, it is not possible to define exact RRP periods. For a rapid evaluation of RRP before shipment from the nursery, a standard of 10 days might be adopted; for longer evaluations standard periods of 20, 30, or 40 days should be preferred.

4. The post-planting or post-outplanting environment cannot be defined exactly as it will have to be varied to meet the specific requirements of some species. For many species the following environment is suitable and is to be preferred as a standard:

Light - 16 to 20 hour photoperiod with >50 000 lux illumination 12 hours per day.

Temperature - 25°C (77.0°F) during the day, 17.5°C (63.5°F) during the night.

Humidity - 50-60% RH during the day, 80-100% during the night.

The methods used to evaluate RRP all involve 1) the measurement or encoded description of one or more of the above attributes of the root systems (items A, B, C, and D) of a sample batch of seedlings; 2) growing the seedlings in soil or soil-less culture for a specific time period in a specific environment; and 3) remeasuring the root system at the end of the time. The review of literature that follows is included to provide information and insight on the development of root regeneration methodology.

LITERATURE REVIEW

The importance of Root Regenerating Potential (RRP) as a measure of the physiological quality of nursery stock was not identified in Wakeley's (1948) pioneer work on this important topic. Thus, although Wakeley found that there were acute physiological differences between seedlings of similar morphological quality, he did not discuss RRP. Even today, many silviculturists tend to depend on classification of the morphological attributes of nursery stock rather than on physiological attributes because the former are more readily defined and measured (Day 1980). Because RRP, or the ability to initiate or elongate white roots soon after transplanting, is the most important attribute of seedling quality, it should be recognized as such.

Simple root regeneration tests have been carried out by many foresters concerned about finding out whether the poor seedling survival they experienced was due to poor stock quality or adverse outplanting environments. To evaluate the problem, they simply potted a portion of the stock to be field planted in a moist forest loam and then compared survival and root and top growth. Stone's historic study published in 1955 differed little from this procedure. From this beginning, the currently methods used to evaluate RRP were developed by Stone and his co-workers (Stone and Schubert 1956, 1959a). Even by 1958, Stone and Schubert (1959) had developed their methodology so that they were

> digging seedlings from the nursery every 15 days, replanting them in the greenhouse after 0, 1, 2, and 3 months in cold storage and redigging them 30 days later and recording any new root growth.... each seedling shipment was subjected to the following treatment. First the white root tips were pinched off. Then the 20-seedling lot was planted--10 seedlings per galvanized container--in sand loam. These planted seedlings were then watered and drained, and the containers were placed in a 20°C (68°F) waterbath in the greenhouse....The air temperature in the greenhouse did not fall below 20°C (68°F) at night but with few exceptions did not exceed 35°C (95°F) in the daytime....After one month in this greenhouse environment, each galvanized container was lifted from the waterbath and the soil carefully washed from the seedlings....The root systems of the seedlings were then examined and elongating laterals which had just started to suberize, but which could still be recongized as new roots were counted.

By use of these techniques Stone and Schubert were able to show that the RRP of ponderosa pine (*Pinus ponderosa* Laws.) varied greatly with the time of year in which the seedlings were lifted and outplanted. Later Stone *et al.* (1962) also showed that the RRP of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) varied with lifting and outplanting date. In this work a more comprehensive analysis of the seedling root systems and the measurement of RRP was made:

> Douglas-fir seedlings in common with most conifers have an heterorhizic root system with a primary root, several elongated first and second order laterals and many short first, second, third, and fourth order laterals varying in size from short protuberances to laterals several inches or more in length. When these seedlings are removed from the seedbed or transplant bed, varying portions of the the primary roots as well as most of the elongated laterals and many of the short laterals, particularly if they are in a growing state, are broken off and left in the ground. Thus when seedlings are planted in the planting site, the root systems that are regenerated subsequently must come from one or more of the following: (1) short unbroken laterals that begin to elongate rapidly; (2) lateral roots that originate at points where older roots have been removed; (3) lateral roots that originate some distance back from wound tissues and apparently are not associated with them.... Seasonal variation (in RRP) is measured in both lateral root elongation potential and lateral initiation potential which together are hereafter referred to as "root regenerating potential"....

In 1963, Stone *et al.* showed the root regeneration potential of ponderosa pine seedlings produced by four California nurseries varied not only with lifting and outplanting date but also with the source nursery. In 1966, Krugman and Stone showed that cold nights enhanced the RRP of ponderosa pine. In this study they still used the methods described in Stone and Schubert (1959a). By 1967, Stone had begun to improve RRP methodology:

> According to the technique that we have used, seedlings whose RRP is to be evaluated are (root) pruned....and all the white root

> tips longer than 0.25 cm are pinched off....merely to simplify subsequent counting procedures. The seedings are planted in screened blended forest soil....Following planting the trays are suspended in 20°C water baths for 28 days....Roots that have grown 1.0 cm or more -all new growth is white and easily recognized-are measured and recorded with respect to origin....Until recently, the controlled temperature baths were located in glass houses in which air temperatures fluctuated widely but were not allowed to fall below 18°C during the night. The water baths are now located in controlled environment chambers in which the air temperature is maintained at 25°C during the day and at 18°C during the night; the light intensity is maintained, with water cooled Zenon-arc lamps, at 3,500 foot candles (37,650 lux).

Stone (1967) and Stone and Jenkinson (1970) showed that ponderosa pine seedlings transplanted into soils initially moistened over a range of available soil moisture percentages varied in RRP. In most seasons, soil moisture tensions greater than 0.5 to 1.0 bar appeared to limit RRP. However, in January when RRP is highest in California, roots were regenerated in soils with tensions up to 7 bar.

RRP research in Canada began after a visit by Dr. E.C. Stone to the Faculty of Forestry at the University of Toronto in 1969. Initial studies at Toronto (Hambly 1973) were followed by more comprehensive studies of RRP at the School of Forestry at Lakehead University in Thunder Bay (Stupendick 1973; Day and Stupendick 1974; Day and Butler 1975; Day and MacGillivray 1975; Mahon 1976; Kenny 1976; Fraser 1976; Day 1976). These studies were in most respects similar to those carried out by Stone and his associates with the exception of the use of the Rhizometer (Morrison and Armson 1968) and glass-fronted root boxes (Lavin 1961; Larson 1962; Musik *et al.* 1962). Day and Stupendick point out the change in approach to RRP study as follows:

> An important difference between this study and that of previous workers is the use of the Rhizometer (Morrison and Armson 1968) for the measurement of 'Root Area Index' or 'RAI' of seedlings under study. Previous workers' methods of counting and measuring the length of newly regenerated roots was not used because of limited time and funds....Sixty seedlings were potted as before in waxed cardboard containers for study of RAI response and twenty seedlings were planted against the glass in 30.5 cm (12 in) by 15.75 cm (6 in) by 3.0 cm (1.2 in) glass fronted root boxes. The root boxes were sloped at 45° during the root response period so that newly elongating roots could be demarkated and measured against the glass.

In the United States, Stone and his co-workers continued their research on RRP in the 1970s. This work resulted in publications on the modification of nursery climate to improve RRP (Stone and Norberg 1971) and on physiological grading (Stone and Jenkinson 1971) and culminated in a summary of all the RRP work in 'Reforestation practices for conifers in California' by Schubert and Adams (1971). In Canada, Day and MacGillivray (1975), Day and Butler (1975), and Polhill (1975) were working on the RRP of nursery stock after transplanting in soil at field capacity, 0.1 bar, and at 0.5, and 1.5 bars soil moisture tension. Day and MacGillivray (1975) describe the work:

> Eight seedlings were planted in each of three sets of root boxes that contained sandy loam soil adjusted to 0.1, 0.5 and 1.5 bars

> SMT (soil moisture tension)....The root boxes were 30.5 x 15.25 x 2.54 cm (12 x 6 x 1 in)...and there were 16 equally spaced 2 mm holes in the back (for irrigation to replace water used by pipette) ....Newly developed roots and the extension of old roots were traced on the glass at 4- and 6-day intervals. At the end of the 40-day period....The RAI of each seedling was remeasured and compared with the initial RAI to obtain the increment or decrement that had occurred....

These studies showed that the RRP of white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.) and jack pine (*Pinus banksiana* Lamb.) was generally high in the spring, low during the summer, and moderate in the fall. They also showed that RRP tended to be very low in soils at more than 0.5 bar tension, although jack pine was less severely affected than the spruces.

In 1976, RRP studies at Lakehead University were continued with: 1) a study of plant moisture stress (-water potential) - RRP relationships (Mahon 1976); 2) a study of fall chilling on the RRP of overwinter cold-stored red pine (*Pinus resinosa* Ait.) (Fraser 1976); and 3) a study of cool (+2°C) and frozen (-2°C) storage on the RRP of spring lifted white and black spruce stock (Kenny 1976). In 1976, Day and Day *et al.* summarized the results of their work on the effects of planting date and the moisture content of the outplanting soil on RRP. Finally, in 1977, Day and Breunig showed that the RRP of white spruce was significantly better for seedlings with large (≥ 30.0 cm^2) RAIs than of those with either 10 or 20 cm^2.

In 1976, Lee and Hackett published their work on the RRP of *Pistacia chinensis* in a 'bottom mist chamber'. Although this work was not known to the Canadian workers, it is of considerable interest because it antedates the root misting work now in progress at Lakehead University:

> The root regenerating potential (RRP) of one year old *Pistacia chinensis* seedlings at different growth stages was determined by recording the number of newly initiated roots during the period of weeks after bare-root transplanting into a bottom mist chamber.... Root systems were mist irrigated in a chamber covered on the sides and ends with black polyethylene film to exclude light and aluminium foil to reduce radient heating. The top of the chamber was covered with pieces of 1.8 cm (3/4 inch) thick styrofoam between which the seedlings were inserted for support....Misting frequency for roots was 5 sec. per 5 min. 24 hours a day....

In 1977 and 1979, Burdett wrote on assessing stock quality by means of physiological tests carried out in an inexpensive semicontrolled environment chamber, and on new methods of evaluating RRP. One of the methods was the well-known displacement technique (Iyer, not dated) that provided root volume measurements. The other was a coding system devised by the author. Burdett (1979) described his work in British Columbia as follows:

> The survival and growth of lodgepole pine (*Pinus contorta* Dougl. ex. Loud.) planted in the spring under a variety of conditions was found to be closely related to its root growth capacity as measured by two newly developed methods. One method employed a displacement technique to measure the root volume of the test seedlings, nondestructively, both at the beginning and end of the

> period of growth under standard conditions. The change in root volume that occurred during the test was taken as a measure of the root growth capacity. The other method of measuring was to record, by means of a semi-quantitative scale, the number of newly elongated roots possessed by the test seedlings after 1-week.

In fact, the semiquantitative scale proposed by Burdett (1979) (i.e., 0 = no new roots; 1 = some new roots, none over 1 cm of length; 2 = 1 to 3 new roots over 1 cm in length; 3 = 4 to 10 new roots over 1 cm in length; 4 = 11 to 30 new roots over 1 cm in length; and 5 = more than 30 new roots over 1 cm in length) was similar to the 'root phenology codes' described by Kenny (1976), Day and Breuning (1977), and Mears (1978).

In 1979, Herman and Lavender outlined methods for testing the vigor of Oregon species in pots filled with forest soil and placed either in a growth room or greenhouse. Although RRP was not evaluated and bud flush and survival alone were used to evaluate physiological quality, the tests are pertinent because both nonstressed and stressed seedlings are tested:

> The physiological quality of the seedlings will become apparent more quickly if the seedlings are stressed....The most common stress treatment is to expose the roots and shoots to 90°F (32.2°C) and a relative humidity of 30 percent for 15 minutes just before potting the seedlings....After 4 weeks, bud flush and survival will indicate the vigour of most trees.

In 1979, MacDonnel (1980) began to develop an intermittent root mist chamber (RMC) at Lakehead University in order to attempt to find a rapid practical method for evaluating RRP *before* stock is shipped to the planting site.

> The (root mist) chamber was developed to provide a rapid method of estimating root regeneration potential of nursery stock by evaluating root growth capacity before stock is shipped to the planting site....The results of initial tests show that the RMC gave values for root growth capacity (in terms of percent root activity) that were not significantly different from tests carried out in soil (peat-vermiculite mix in pots)....This suggests that the RMC method will be satisfactory in providing an accurate and rapid measure of root growth capacity for an estimation of root regeneration potential.

The current methods of evaluating RRP now in use at Lakehead University will be the focus of the remainder of this paper.

CURRENT METHODS OF EVALUATING ROOT REGENERATING POTENTIAL

From 1980 to 1983, a new program of research on 'Morphological and physiological stock quality in relation to field outplanting performance' is being conducted at Lakehead University.

The objectives of the research are:

To prepare test lots of 1½+1½ white and black spruce and 2+0 jack pine nursery stock by varying lifting data and storage treatment, i.e., 1) spring lifted, 2) spring lifted and cold stored at +2°C, 3) fall lifted and frozen stored at -2°C, and 4) fall lifted and frozen stored at -2°C, but preconditioned for 3 and 6 weeks at +2°C before planting.

To plant the test lots of stock over a 63-day period in the spring, i.e., 1) May 5, 2) May 26, 3) June 6, and 4) July 7, both in pots in a standard growth chamber environment for bioassay of RRP and on two field sites.

To measure the physiological and morphological quality of each lot of stock before and after planting and to correlate these measurements with survival, growth, and other measures of performance.

In 1981 it was possible to bioassay sample lots of 15 to 25 seedlings from each of the treatments included in the research in 1) pots, 2) root mist chambers, and 3) root growth boxes. In each case the seedlings were measured, grown for 21 days, and remeasured to evaluate the change in top and root characteristics. In addition, identical lots of stock were planted on two field sites, a sandy outwash plain and a shallow till, 80 km north of Thunder Bay.

It is too early to comment on the results of this research, but it appears that the results of the three bioassay methods are very similar to field results.

In the laboratory bioassays and field trials all seedlings are measured, grown for 21 days, and remeasured. In the root mist chamber and root growth boxes the seedlings were also remeasured at 10 days to provide a rapid estimate of RRP. In the field trials, one-third of the seedlings planted were removed 21 days after planting. In all tests, 80-column data processing forms were used to record information on individual seedlings. Columns 8 to 16 were for Identification. As the study involved initial (x) and final (y) measurements, both were recorded as follows:

TOP CHARACTERISTICS--Columns 17 to 41

17 & 18	Total Height in cm (x)		
19 & 20	Root Collar Diameter in mm (x)		
21 to 24	Height Growth in cm (x & y)		
25 to 28	Shoot Volume in cm^3 (x & y)		
29 & 30	Physiological Condition Code (x & y)		
	0 =	Foliage Healthy (Green)	
	1 =	0-25	Brown and/or Defoliated
	2 =	26-50	
	3 =	51-75	
	4 =	76-100	
	5 =	Dead (Buds and Inner Bark Dry)	
31 & 32	Phenological Condition Code (x & y)		
	0 =	Buds Dormant	
	1 =	Buds Swelling	
	2 =	Buds Bursting	
	3 =	Short Shoot Elongation	
	4 =	Medium Shoot Elongation	
	5 =	Long Shoot Elongation	
33 to 38	Plant Moisture Stress (PMS in bars) (x & y)		

39 to 40 PMS Calculator Code (Day 1980) (x & y)

1 = Normal
2 = Moderate
3 = High
4 = Excessive
5 = Lethal

ROOT CHARACTERISTICS--Columns 41 to 78

41 & 42 Root Area Index in cm^2 (x & y)

45 to 52 Number and Length of Small Root Tips (0.0-2.0 mm, mean 0.2 mm)

Code	Number	Equivalent Length in cm
0	0	0.0
1	1-10	0.5
2	11-20	1.5
3	21-30	2.5
4	31-40	3.5
5	41-50	4.5
6	51-60	5.5
7	61-70	6.5
8	71-80	7.5
9	>80	8.5

53 to 60 Number and Length of Medium Root Tips (3.0 to 10.0 mm, mean 0.6 mm)

0	0	0.0
1	1-10	3.0
2	11-20	9.0
3	21-30	15.0
4	31-40	21.0
5	41-50	27.0
6	51-60	33.0
7	61-70	39.0
8	71-80	45.0
9	>80	51.0

61 to 66 Number of Long Root Tips (>1.0 cm) (x & y)
67 to 72 Length of Long Root Tips in cm (x & y)
73 to 78 Length of All Root Tips in cm (x & y)

The above recording system provides most of the essential information needed to evaluate the post-transplanting or post-outplanting response of the seedlings under test. It is obviously designed for scientific rather than operational use of the nursery; however, the above coding system could be made more operational by providing a coding system for long root tips (>1.0 cm).

The pots, root mist chambers, and root growth boxes used for the bioassay are briefly described in the following conclusion.

1. Pot Bioassay Method

a. From three to five replications of five seedlings (the number planted per pot will depend on root system size) are planted in a standard 2:1 peat:vermiculite mix in 23-cm (9-in.) plastic bulb pans (the size of the bulb pan is increased if necessary).

b. The peat-vermiculite mix is irrigated to field capacity and the bulb pans of test seedlings are placed in a growth chamber programmed to provide:

Light- 16 to 20 hour photoperiod with 12 hours >50 000 lux.
Temperature- 25°C day and 17.5 °C night.
Humidity- 50-60% RH day and 80-100% RH night.

2. Root Mist Chamber (Figure 1)

a. From three to five replications of five seedlings are vertically fixed in the RMC support frames so that their roots hang down in the enclosed chamber and their shoots extend upward outside it. The spray-jets in the chamber are programmed to provide 5 seconds of mist every 30 minutes, or sufficient mist so that the roots are always coated with a fine moisture film.

b. The root mist chambers are placed in growth chambers that are programmed to provide exactly the same environment as in 1.b above.

3. Root Growth Boxes (Figure 2)

a. From three to five replications of five seedlings are set, three to a pad, sequentially in the root growth boxes. The seedlings are slipped between the jacket or sleeve of polyethylene and on top of the pad of polyurethane foam. The roots must be spread with care and the planted pads must be packed tightly between the polyfoam spacers so that the seedlings remain in a vertical position.

b. The polyurethane foam adjacent to the seedling roots is fully irrigated night and morning to ensure that the pads are moist at all times. The root growth boxes are placed in growth chambers programmed to provide exactly the same environment as in 1.b above.

ACKNOWLEDGMENTS

The research support of the Ontario Ministry of Natural Resources over the last decade is recognized with appreciation. Renewed support of the Ontario Ministry of Natural Resources and the Canadian Forestry Service during 1980-83 is again recognized with much appreciation.

Thanks are due to Ken Reese for coordination, to Dolf Wynia for the unlimited use of the Thunder Bay Forest Station and for making me feel as if I was a member of his staff, and to Paul Webb for scientific advice and for moral support.

Special thanks are due to all those who work (and put up) with me, especially Eileen Harvey, Beverly Shaw, Lynn Palmer, Gary Gilbert, and any other associates and students I have missed.

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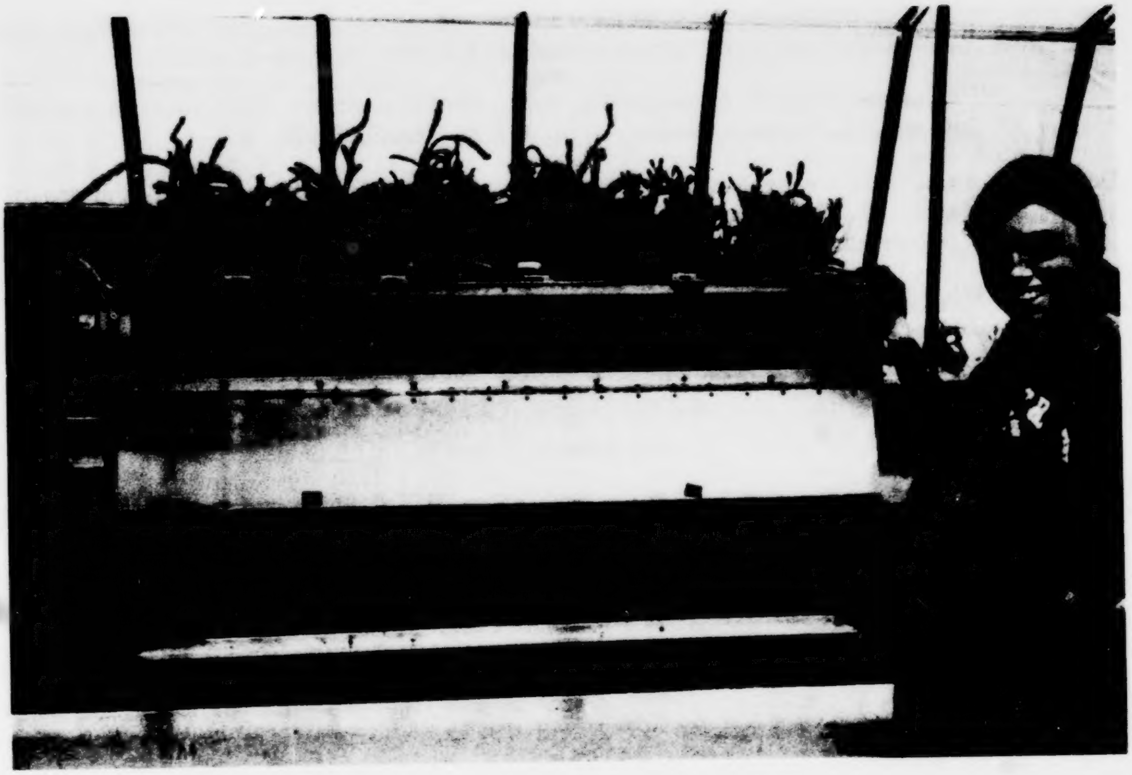

Figure 1. The root mist chamber with window exposed for viewing roots.

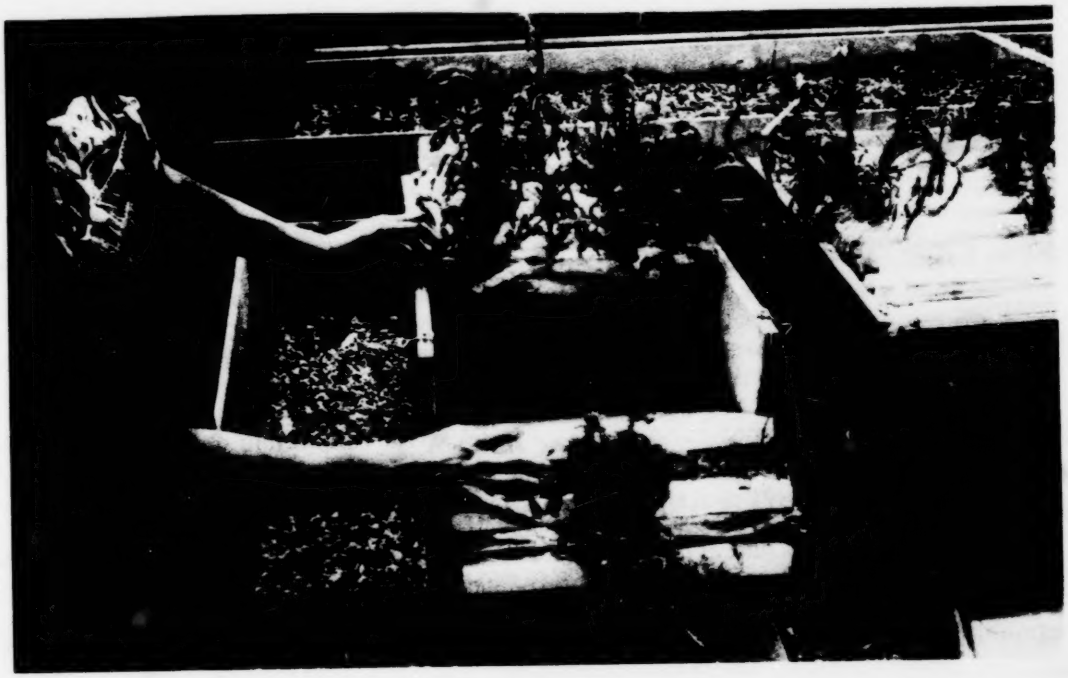

Figure 2. Root growth boxes opened to show roots.

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USING COST ACCOUNTING IN NURSERY MANAGEMENT

A. Wynia
Thunder Bay Forest Station
Ontario Ministry of Natural Resources
Thunder Bay, Ontario

Controlling costs is a vital management function. As nursery managers we play a major role in controlling the cost of reforesting every hectare of cutover that must be planted.

At the nurseries we have learned many ways of saving money; however, in the field I have seen an ever-increasing demand for more expensive stock, where consumers are not held accountable for costs but only for results in terms of survival and growth. With the skyrocketing costs of tree planting this may not be an undesirable trend, but because many of my remarks are directed towards nurserymen, I also appeal to our tree planters to get their priorities in order with respect to spending in reforestation. Whoever spends it, we must give the taxpayer value for his money. All expenses should be controllable by someone at some level.

Obtaining cost accounting information on a bare-root production nursery is different from a manufacturing situation due to the time span of 2 to 5 years and the influence of many uncontrollable cost factors. Present inflation rates make historic costs useless. As well, changes and improvements in production processes need to be assessed at least annually and preferably more often.

Twenty years ago, one of my predecessors at Thunder Bay (E.M. Cressman) foresaw the problem of historic costs, however they might be obtained, and developed the concept of determining production costs based on age classes. Over the years this principle has been expanded and the system is now being used on a provincial scale. Recently we have been able to integrate it into the provincial Management Information System (MIS). We feel now that we have a workable system involving a minimum amount of record-keeping and yet providing us with adequate information and, most of all, flexibility to analyze the effect of any procedure we may wish to study in isolation.

The cost accounting system consists of the following components, all of which are part of our regular administration:

1. records of inventory in numbers and hectares occupied for each age class, species, and seedlot, with a forecast of numbers of trees expected to be shipped in the appropriate year,

2. records of expenditures by age classes and a number of variable and non-variable overhead and "suspense" accounts,

3. allocation of our available funds into the "slots" where they are expected to be spent and a monthly MIS update so that we can regularly compare our expenditures with our plans,

4. an annual report on our production costs made up from the accumulated age class unit costs plus the current shipping cost with prorated overhead costs included,

5. the cost records of our container stock production, which have been integrated with the age class record system even though because of the short production period we can use historic costs for them, and

6. a report that at the completion of the shipping year is sent to all client districts that have received trees and shows the production costs associated with each of the age classes of stock that they received.

Due to the policy of the provincial government, we cannot include capital costs or seed costs even though it would not be difficult to incorporate them as direct costs and overhead prorated costs. Operating improvements as a result of capital investments therefore show directly as savings. All coding for the system is done daily by a senior nursery staff member and takes less than 15 minutes.

The annual and monthly computer-produced MIS reports summarize all expenses of the nursery under the regular MIS categories such as permanent salaries, seasonal salaries, services, communication, etc., for each specified production cost code. The input for the MIS reports are the processed and pending coded payrolls and invoices submitted to our financial branch. The month-end report is usually available within 1 week after the end of each month.

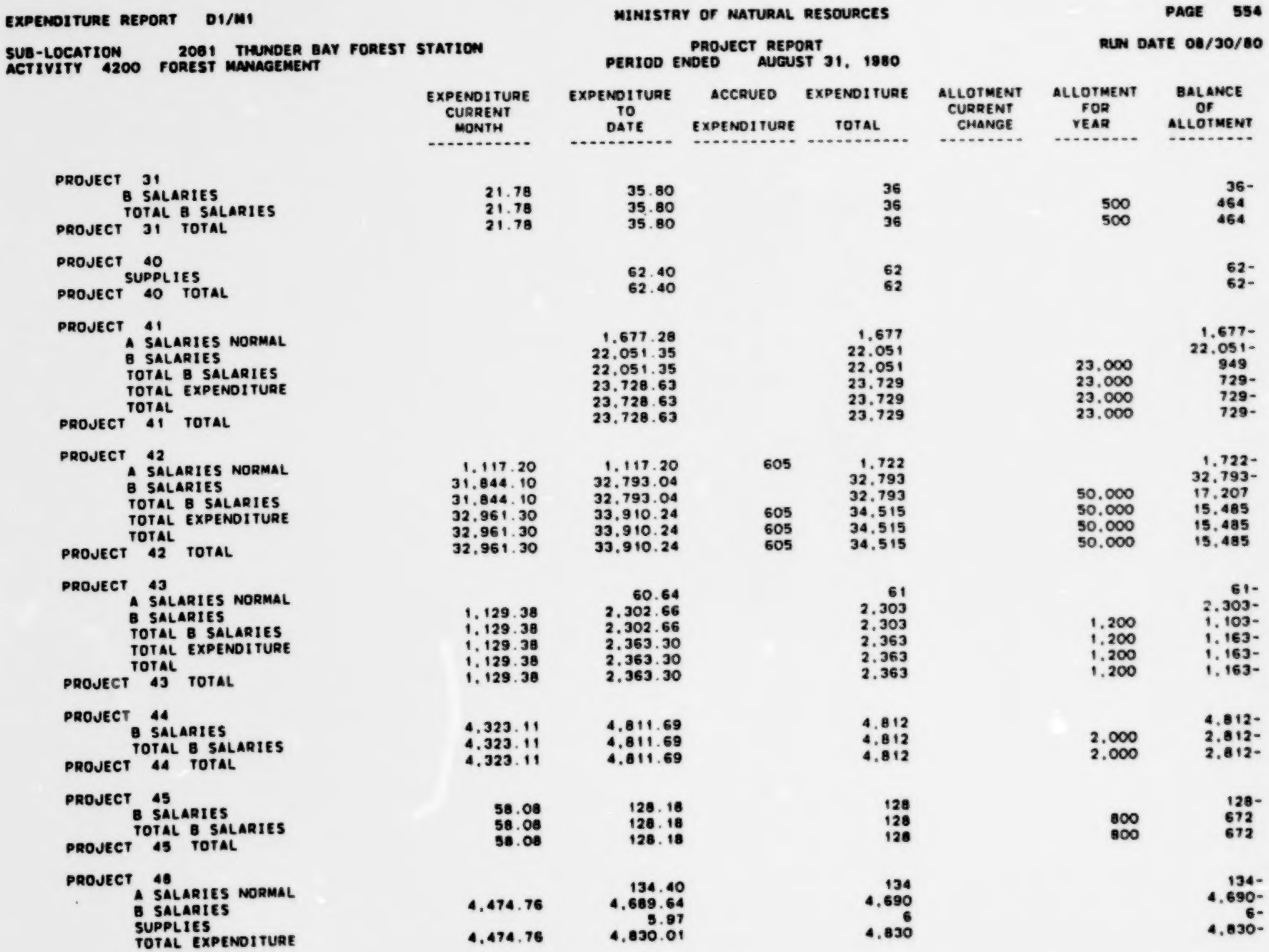
For example, all costs associated with transplanting 1½+1½ stock, weeding it, and fertilizing it in the fiscal year are shown by codes and categories for review and analysis. They are totalled to obtain the annual direct expenditure on that age class. Figure 1 shows a page of this monthly MIS report.

The indirect expenditures are shown elsewhere and include land preparation, irrigation, fertilizer purchases, etc., and overhead. The former costs are obtained from holding accounts and are assigned on the basis of acreage occupied and the latter are prorated on the basis of total direct expenditures. Some shifts may be required to adjust for large changes in operating procedures, as when insufficient land has been prepared for transplanting due to increases in targets.

When the total costs have been determined for each age class by product in the fiscal year, including overhead costs and special adjustments, the current inventory and forecast provide the information needed to obtain the per thousand cost component of that year for that product. By simply adding the current year's component costs, a total cost rating can be obtained.

Table 1 illustrates a very simple calculation of costs for a nursery producing 1+0, 2+0, and 3+0 stock. Using the same approach of determining cost ratings rather than historic costs also avoids the problem of the discrepancy between fiscal years and shipping years in our production process.

Having plenty of "slots" in which to place costs of special interest within the age class category enables a nurseryman to pinpoint certain operations in which he is particularly interested. For example, we are currently looking at the impact of our mechanical harvester on our shipping costs. Costs associated with shading during the first year for some species and not others can be separated out if desired. We have found a two-digit decimal breakdown quite adequate. Table 2 is an example of a section of our coding manual.



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EXPENDITURE REPORT   D1/M1                                 MINISTRY OF NATURAL RESOURCES                                          PAGE   554

SUB-LOCATION       2081  THUNDER BAY FOREST STATION                 PROJECT REPORT                                       RUN DATE 08/30/80
ACTIVITY   4200  FOREST MANAGEMENT                            PERIOD ENDED     AUGUST 31, 1980
                                          EXPENDITURE   EXPENDITURE     ACCRUED    EXPENDITURE   ALLOTMENT   ALLOTMENT    BALANCE
                                            CURRENT         TO                                    CURRENT       FOR          OF
                                             MONTH         DATE       EXPENDITURE     TOTAL       CHANGE       YEAR      ALLOTMENT
                                          -----------   -----------   -----------  -----------   ---------   ---------   ---------

    PROJECT  31
          B SALARIES                            21.78         35.80                        36                                  36-
          TOTAL B SALARIES                      21.78         35.80                        36                     500          464
    PROJECT  31  TOTAL                          21.78         35.80                        36                     500          464

    PROJECT  40
          SUPPLIES                                            62.40                        62                                  62-
    PROJECT  40  TOTAL                                        62.40                        62                                  62-

    PROJECT  41
          A SALARIES NORMAL                                1,677.28                     1,677                                1,677-
          B SALARIES                                      22,051.35                    22,051                               22,051-
          TOTAL B SALARIES                                22,051.35                    22,051                  23,000          949
          TOTAL EXPENDITURE                               23,728.63                    23,729                  23,000          729-
          TOTAL                                           23,728.63                    23,729                  23,000          729-
    PROJECT  41  TOTAL                                    23,728.63                    23,729                  23,000          729-

    PROJECT  42
          A SALARIES NORMAL                  1,117.20     1,117.20          605         1,722                                1,722-
          B SALARIES                        31,844.10    32,793.04                     32,793                               32,793-
          TOTAL B SALARIES                  31,844.10    32,793.04                     32,793                  50,000       17,207
          TOTAL EXPENDITURE                 32,961.30    33,910.24          605        34,515                  50,000       15,485
          TOTAL                             32,961.30    33,910.24          605        34,515                  50,000       15,485
    PROJECT  42  TOTAL                      32,961.30    33,910.24          605        34,515                  50,000       15,485

    PROJECT  43
          A SALARIES NORMAL                                   60.64                        61                                  61-
          B SALARIES                         1,129.38     2,302.66                      2,303                                2,303-
          TOTAL B SALARIES                   1,129.38     2,302.66                      2,303                   1,200        1,103-
          TOTAL EXPENDITURE                  1,129.38     2,363.30                      2,363                   1,200        1,163-
          TOTAL                              1,129.38     2,363.30                      2,363                   1,200        1,163-
    PROJECT  43  TOTAL                       1,129.38     2,363.30                      2,363                   1,200        1,163-

    PROJECT  44
          B SALARIES                         4,323.11     4,811.69                      4,812                                4,812-
          TOTAL B SALARIES                   4,323.11     4,811.69                      4,812                   2,000        2,812-
    PROJECT  44  TOTAL                       4,323.11     4,811.69                      4,812                   2,000        2,812-

    PROJECT  45
          B SALARIES                            58.08       128.18                        128                                 128-
          TOTAL B SALARIES                      58.08       128.18                        128                     800          672
    PROJECT  45  TOTAL                          58.08       128.18                        128                     800          672

    PROJECT  48
          A SALARIES NORMAL                                  134.40                       134                                 134-
          B SALARIES                         4,474.76     4,689.64                      4,690                                4,690-
          SUPPLIES                                             5.97                         6                                   6-
          TOTAL EXPENDITURE                  4,474.76     4,830.01                      4,830                                4,830-
```

Figure 1. Sample page from a monthly MIS report.

Table 1. Schematic calculation of nursery stock production costs

Age class	Recorded	Ha	Land costs	Total operating cost	Office prorated	Total costs
1-0	10 000	26	3 569	13 569	2 714	16 283
2-0	5 000	20	2 745	7 745	1 549	9 294
3-0	3 000	5	686	3 686	737	4 423
Maintenance land costs	7 000	51	7 000	25 000	5 000	30 000
Office	5 000					
Fixed costs	10 000					
	40 000					

Age class	Product	Ha	Costs	Inventory (mm)	Cost/M	Forecast ship (mm)	Success ratio	Cost rate/M	Acc cost rate/M	Total production cost rating/M
1-0	1-0	6	3 757	4.0	.94	3.7	.80	1.18	1.18	2.03
	2-0	15	9 395	17.0	.55	11.1	.66	.83		
	3-0	5	3 131	3.0	1.04	1.8	.60	1.73		
2-0	2-0	14	6 507	10.5	.62	6.3	.60	1.03	1.86	3.35
	3-0	6	2 787	2.5	1.11	1.9	.76	1.46		
3-0	3-0	5	4 423	2.1	2.11	1.7	.81	2.60	5.79	7.72
			30 000							

$\frac{\text{Total costs}}{\text{Variable}} \quad \frac{40\ 000}{30\ 000} = 1.333$

The values that I as a nursery manager have been able to derive from our age class costing are as follows:

1. Cost problems show up in the year and at the time that they occur and in the exact location where improvement may need to be made.
2. Operational improvements show up as savings immediately, providing managerial flexibility within the nursery system and also at higher levels.

Table 2. Cost accounting codes (TBFS - 2061) 1978/79

4265	NURSERY COST ACCOUNTING FOR STR (Cont'd.)
Projects:	
Div. 4	First-year Transplants, i.e. 2-1, 1½-1½, 1-1
40	STR transplant share of land preparation from Job 80
41	Transplanting 2-1, includes lifting and transportation to transplant field as well as transplanting
42	Transplanting 1½-1½
43	Weeding 2-1, Manual and chemical, LABOR only
44	Weeding 1½-1½, Manual and chemical, LABOR only
45	Application of fertilizer, top dressings, fungicides, insecticides, LABOR only
46	
47	
48	Tape transplanter
49	Holland transplanter rebuild

* Prorated at year end from Job 80.

IFSCO CONE HANDLING AND DRY KILN SYSTEM

R.W. Bell
International Forest Seed Co.
Birmingham, Alabama

To introduce the International Forest Seed Company (IFSCO) cone handling and dry kiln system, the reasons IFSCO wanted a new drying system must be explored.

First of all, IFSCO was in the forest seed business and dealt in large volumes of southern pine seed. The company had processed as many as 130 000 bushels of cones in one season, so there was a great need for a cone drying system that could handle large volumes economically and that would at the same time ensure the highest seed quality.

Secondly, with source identification of seed lots so very important and with the prospects of custom-processing genetically improved seed, there was a need for a system to retain lot identity. It was determined that the system had to process any size lot without losing identity, and production could not be sacrificed.

The third reason was to improve the economics of operating a cone drying system. The system could not be labor intensive nor could it require large amounts of fuel for operation.

After searching extensively, all these features could not be found in any one existing cone drying system. Most cones were being handled by hand in small burlap bags, which was labor intensive, or they were being handled in bulk quantities, which lost lot identities or seed quality.

As far as cone dry kilns were concerned, none of the existing systems were satisfactory. The tumbler dryer system was locked into small volumes or required pre-drying facilities for cones. The large stationary dry kilns sacrificed lot identity and were very labor intensive. Many of you have probably considered these same areas if you have done cone processing or if you are considering doing it.

After several years of experimenting and testing, the present IFSCO cone drying system was developed. IFSCO is utilizing this system in its plants and several are in operation in the U.S. Forest Service and industry facilities.

The cone container has several features that IFSCO was looking for. It could be handled with a forklift (which cut down on labor), it handled up to a 20 bushel-volume of cones in one container, it provided adequate air circulation for the cones, and the crate cost was economical.

As for the operating features of the dry kiln, several are important to IFSCO. First, the unit has a thermostatically controlled temperature system. It can hold a constant drying temperature throughout the drying cycle, or the temperature can be varied as desired.

Secondly, humidity is monitored constantly during the drying time. Here again, a constant setting can be used, or it can be varied according to environmental conditions.

A third feature is the stackable tray. Each tray is individually handled with a capacity of six bushels of unopened cones. Trays can be stacked six high, and any tray can be individually inspected during the drying process. The tray is constructed primarily of wooden parts, which helps in insulation during drying. Tray bottoms are constructed from perforated metal.

A water injection system is another feature. This system is used when there may be unusual cone characteristics or circumstances that would require moisture to be applied to cones after they are in the trays. Water can be added to the cones after they have been dried, and the cones will close back to nearly the original size. This is helpful in the southern U.S. in opening early-picked cones.

Another feature of the system is the unique heated air recirculation system. The air passes through the cones and by a ductwork system is recirculated to the heating system. The air is automatically monitored for humidity, and optimum use is made of its moisture absorption capacity. When the air becomes saturated with moisture, shutters automatically open, moist air is expelled, and dryer air is taken in.

Fuel consumption is another important feature. Natural gas, propane gas, or fuel oil can be used; however, natural gas or propane gas is recommended since it tends to burn cleaner. By recirculation, the fuel consumption has been reduced by approximately 60% over conventional noncirculating systems.

Portability of the system is also a benefit. The entire dry kiln can be loaded on flatbed trucks and transported wherever necessary. The system is never tied to a permanent location.

The following is a description of how the cone handling and drying system works. Figure 1 shows the flow process for the system; however, you must keep in mind that these procedures may be varied to suit different conditions.

To operate the system, a 2500-pound lift capacity electric forklift is used. This machine is equipped with a special rotating fork positioning attachment. The special use of this attachment can be seen as the dry kiln operation is explained. The attachment can be mounted on most any forklift with the addition of hydraulic valves to handle operation.

The cones are gathered from either seed orchards or natural stands. They are put into the 20-bushel crates in the field and are transported to IFSCO plants by flatbed trucks. As cones are received at IFSCO plants, they are stored in open field conditions. They are held there to complete the after-ripening process, which allows the seed to mature. This requires approximately 5 weeks from harvest.

The cones are then dumped into a hopper by forklift with the special rotating fork. This hopper has a capacity of 225 bushels.

To fill the dry kiln unit initially, trays are filled individually as they are removed from the dry kiln. Each tray receives approximately six bushels of cones, allowing room for expansion and proper air circulation.

After the cones have been dried properly, the unit can be emptied. Trays containing dried cones are removed from the unit and the cones are dumped into a hopper. This hopper feeds the cone tumbler, which extracts the seed from the cone.

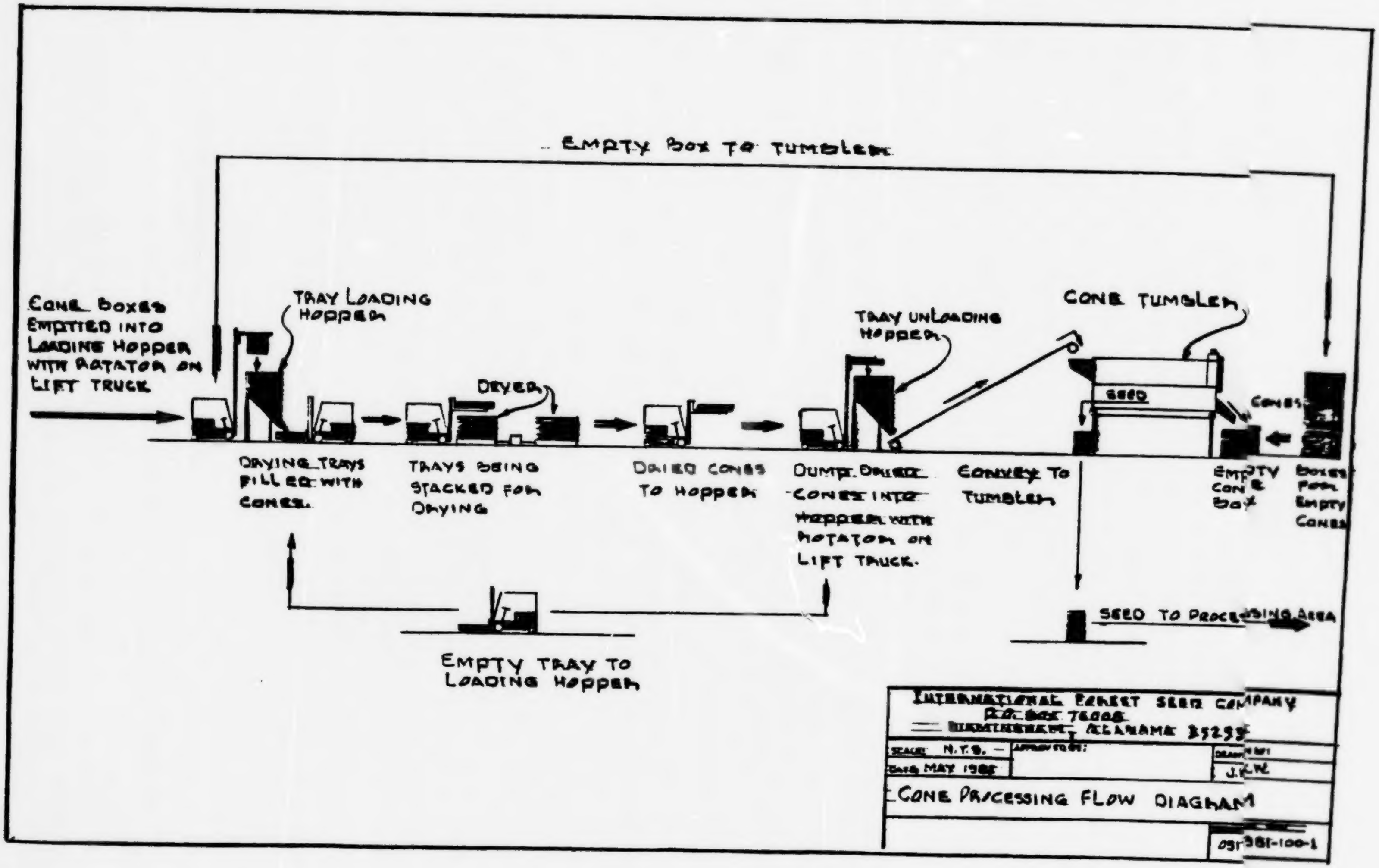
EMPTY BOX TO TUMBLER
CONE BOXES EMPTIED INTO LOADING HOPPER WITH ROTATOR ON LIFT TRUCK
TRAY LOADING HOPPER
DRYER
TRAY UNLOADING HOPPER
CONE TUMBLER
SEED
CONES
DRYING TRAYS FILLED WITH CONES.
TRAYS BEING STACKED FOR DRYING
DRIED CONES TO HOPPER
DUMP DRIED CONES INTO HOPPER WITH ROTATOR ON LIFT TRUCK.
CONVEY TO TUMBLER
EMPTY CONE BOX
BOXES FOR EMPTY CONES
EMPTY TRAY TO LOADING HOPPER
SEED TO PROCESSING AREA
INTERNATIONAL FOREST SEED COMPANY
P.O. BOX 76008
BIRMINGHAM, ALABAMA 35253
SCALE: N.T.S. —
APPROVED BY:
DRAWN BY:
DATE: MAY 1985
J.K.W.
CONE PROCESSING FLOW DIAGRAM
051-381-100-1

Figure 1. IFSCO cone handling and drying system.

After a tray is emptied, it is returned to the filling hopper to be refilled. The tray is then stacked back on the dry kiln, and a constant emptying and filling is continued until the unit is completely emptied and refilled.

A complete unit can be emptied and filled in 4 hours using two men and one forklift. This is a volume of 288 bushels of cones, and this volume can be maintained with four to five lot changes.

As for specifics on the drying of cones, IFSCO uses a setting of 110°F or 43°C, which is constant throughout the drying cycle. The humidity dial is normally set for 45%, but this can be varied as needed. Due to the moist conditions of our cones, the humidity remains high enough to keep the shutters open continuously the first 4 or 5 hours and then they open or close as needed. The cones of the species of southern pines that IFSCO deals with are normally dried in 32 to 48 hours.

At these rates of production, 10 000 bushels of cones per dry kiln can be processed in one season. This could vary with different species of cones and different time limits on processing.

The space required for the unit and its operation is 32 feet by 55 feet. This allows 15 feet on each side of the unit for forklift operating space. The unit should be housed in an enclosed or at least a covered building for operation.

Also, to meet some specialized needs, IFSCO designed a hand-operated dry kiln. This unit is also recirculating but it is made for areas where forklifts are not available. The unit has only half the capacity of our standard dry kiln and is considered primarily for special use projects.

CONE HANDLING SYSTEM FROM FIELD TO PROCESSOR

R.M. Schaefer, III
Seedling Production Supervisor
Potlatch Corporation
Lewiston, Idaho

Seed procurement as a part-time, once every 3 years ordeal is coming to an end, especially for newly expanded operations in the northwest intermountain area. Quite often the specifications for quality seed are totally in the hands of the field personnel, after which the final cone storage and extraction work is the total responsibility of a nursery staff or private seed company. To get high quality seed from field to processor, both field and nursery people must put together a well-planned cone collection system. Any breakdown in the system will affect the seed quality, the seedling quality, and the cost.

How much can be paid for high quality seed? Using a seed cost of $5.00/M seedlings produced for a greenhouse container crop, the following chart shows the seed value as percent germination decreases:

Seed values/pound for Douglas-fir container nursery

		Seeds/pound (D.f.)		
% germination	Seeds/cavity	25 M	35 M	45 M
95+	1	$125.00	$175.00	$225.00
75	3	41.67	58.33	75.00
50	6	20.83	29.17	37.50

From the 50% to the 95+% germination seed, the seed value increases *six times*. Actual growing costs associated with the lower germination potential seed are considerably higher than the single sown 95+% seed because the increased seed volume means higher stratification, sowing, and thinning costs. Additional savings for 95+% seed could be as much as $5-20/M in container nurseries. The 95+% germination seed also reduces grower risk from additional failures caused by fungus and low vigor seedlings resulting from poor quality seed.

To get seed with 90+% germination rates is defined in one word: control. The late Charlie Brown of Brown's Seed Company in Vancouver, Washington, presented his Control Items at cone collection seminars. Here are Charlie Brown's items for "control", which Potlatch Corporation has put into action to collect high quality seed:

1. **Early crop analysis in the field.** As early as mid-June, the crop potential of cone numbers can be evaluated. As a general rule in North Idaho: the lower the number of cones, the lower the seed quality. With accurate 5-year to 10-year plans of seed needs, collections should occur only on heavy seed-yield years.

An elementary but important fact to remember is that collection costs and extraction costs are rather fixed; the amount and quality of seed recovered is the major variable. So, unless seed inventories are critically low, only moderate to heavy crops should be collected to avoid higher costs and lower percent germination lots.

2. **Adequate pre-planning to locate and set up needed collection areas.** By utilizing 5- and 10-year plans, actual areas can be selected for future cone harvest. This could involve excluding areas from logging until cones are harvested. Other areas may be set aside indefinitely for cone collection activities.

3. **Type of cone collection.** The type of cone collection--climb and pick, fall trees, and pick or squirrel cache--will have an effect on seed qualilty. Squirrel cache collections should be avoided because it is impossible to consistently get 90+% germination from squirrel cut cones. This is due to two factors:

    a. Squirrel cache collections are characterized by inconsistent maturity levels and large variations in dormancy, resulting in lower and extended germination.

    b. Squirrel cache collections have the high probability that cones and resulting seed will be highly contaminated with various fungi. Tests run at the Potlatch Greenhouse facility have shown up to 14 times more germinate mortality in Douglas-fir squirrel cache seed lots than climb and pick or fall and pick harvested seed lots.

    In many of the squirrel cache lots, correlation between germination tests and greenhouse performance is very poor. Hand-picked cones, on the other hand, usually have operational performance closely related to current germination tests.

4. **Cone maturity monitoring and evaluation.** Training of field people responsible for the collection and handling is essential. Only by having trained people handle the harvest will the control items be adquately enforced.

    Some individuals think that squirrels are the best indicators of cone maturity; however, remember that squirrels are interested in food, not 90+% germination seed! A good example of the squirrel's inability to evaluate cone maturity occurred in 1980. Several seed companies collected *Abies grandis* cones in North Idaho from squirrel cache sources. The seed resulting from several hundred bushels had such low germination percentages that it was not marketable. This could have easily been avoided by people trained to personally evaluate cone maturity.

    Cone maturity evaluations should be initiated by mid-July. This will enable the field personnel to follow the ripening progress and enable accurate estimates for harvest dates to be selected. During this period, other important observations can be made that will affect the quality and amount of seed to be harvested. The observations will include confirming pollination (cut test) and following insect damage and intensity.

5. **Final planning and logistics.** Preparation is one of the most important steps following confirmation of the collectible cone crop.

    a. Have adequate field personnel to handle cone maturity checks, to clean, bushel, and tag cones, and to provide area security and adequate daily cone storage.

b. Have enough clean field collection bags. Dirty, previously used bags reduce quality enough to lower the percentage of the germination testing.

c. Have numbers, volumes, and species to be collected for each preplanned seed lot.

d. Give proper notification to the required number of cone pickers to handle the harvest. This would include the type of harvest, prices paid to collect, cut test specifications, acceptable maturity, etc.

e. Have adquate field storage racks and know the transport plans for moving cones for final drying before processing.

6. **Cone handling procedures.** The following guidelines will ensure quality seed from the cone receiving station to the processor:

a. Cone pickers are required to turn in harvested cones daily. Filled sacks should be kept in the shade during the day and not stacked together, especially not in car trunks.

b. All cones are run over a cleaning table to remove debris, check maturity, perform cut test counts, measure for payment, finally label, etc., by the station operator.

c. The maximum of one bushel of cleaned cones is placed into 1.5 to 2.0 bushel loose-knit burlap bags. The bag is placed as quickly as possible on a portable field drying rack.

Quite often, short distance transport of cones to a more central area is required. Since fresh-picked cones are quite susceptible to heating, arrangements must be made to have the green cones shipped immediately, unloaded, and reracked before heating damage occurs. Green cones can be stacked together for 1-2 hours; you can test for heating by putting your hands between the piled sacks.

d. To promote seed lot homogeneity, the fresh field-racked cones should be allowed to "after-ripen". This simply means the cones should be kept for approximately a 2-week period in a shady, rather cool area; this allows the cones to slowly begin drying.

During this time, the seeds in each cone have time to reach almost equal dormancy levels; if done properly, this can apply to the entire seed lot. After proper stratification, the result will be quick, even germinating seed.

e. Following after-ripening, cones may be air-dried before shipment to the processor. If early shipment for long distances is required to reach the processor, precautions are needed to avoid cone heating. Potlatch Corporation has found, in its North Idaho climate, that 2 months of air-drying brings the seed moisture levels down to approximately 15-20%. At this level, there is no trouble with cone heating if the bags are tightly stacked for 24 hours. But each person responsible for collections will have to determine how best to avoid cone heating.

7. **The processor.** Supervisory people involved with the seed extraction operation are the vital, last link to achieve a 90+% germination seed lot. Asking questions, observing the process, and showing interest will help improve in-house operations or choose a quality seed processing company.

To conclude, the end product is no more than all the steps done correctly to achieve a goal. Since vigorous, high-quality seed is necessary to produce seedlings that meet rigid specifications, both field personnel who are responsible for seed procurement and nursery managers need to help each other through the controlled steps of the cone handling system from field to processor.

AVOIDING THE NURSERY-CUSTOMER WAR

or more aptly

KEEPING THE BATTLES DOWN TO ONLY CUSTOMERS YOU REALLY DON'T WANT TO DEAL WITH ANYWAY

A.E. Suhrbier
Northwest Timber Nursery
Crown-Zellerback
Aurora, Oregon

You must have all heard the following complaints from your customer

30% of your root systems are not acceptable.

All my trees are turning brown.

Half of my transplants are "J" rooted coming out of the bag.

Your trees broke bud before they went into the ground. They heated up in your van.

Your wimpy plugs won't stand up after planting.

Those transplants you sent have roots so long we have to jam them in the ground.

I ordered 100 M trees, how come I only received 89.6 M?

Our plugs are bare-roots by the time we plant them.

I ordered my trees to be grown at 30 per square foot. How come the nursery sows them at 50?

and last but not least

My trees are all dead; I want my money back.

These are all very bad comments, but the worst kind of response is silence. Your customers have their trees grown somewhere else, and all you know is that they didn't order any seedlings from you for the last 2 years or that their orders have been very small lately.

The normal response to the above arrows shot at you by the customer is to ignore them. You know what all your problems are. THERE ARE ONE THOUSAND WAYS TO KILL A TREE, BUT YOU ONLY HAVE TO DO IT ONCE. You may tell these archers that you know what the problem is and that you will do better next time.

A more exciting response to these archers is to throw spears at them. You may be able to kill a tree, but you also know one thousand ways that the customer can do it too:

Tearing the seedlings out of their wrapping.

Storing and transporting the seedlings in the elements.

Packing bags too tight.

Death stomping the seedlings after planting.

Ripping off excess roots.

"J" rooting.

Planting in rotten wood.

Planting in wet spots.

Planting too deep.

Planting too shallow.

I recently was at a nurserymen's meeting that included a field trip. At one of the stops, the area forester paused at an 8-month-old plantation that did not look too good. His trees, which should be Douglas-fir, looked like yellow fir or red fir. Twenty nurserymen, more aptly called "Defenders of the Faith", poured out of the bus and proceeded to find the causes.

Here is one planted too deep.

I found one planted too shallow.

See that scar on the side of that tree, that's from the deadly Death Stomp.

I still wonder what that forester was thinking as he watched us conclude within 50 feet of the road on that steep, rocky, west slope that it was all his fault.

Here we are, locked in deadly combat with our customers, and we probably don't even know it. Can it be avoided? I think it can, but it really hurts. To avoid conflict, someone at your nursery will have to suffer severe withdrawal pains. For 2 to 5 days a month, someone will have to give up the one thing he really needs:

His desk.

His job.

His crew.

You may feel that the above items need you, but I think that sometimes we need them even more. You should do this withdrawal during a time when you feel you really cannot. The best time for this withdrawal will probably be during your lifting or sowing season. Impossible! No way! I have heard these words from myself, but it can be done with some surprising results.

First, schedule well in advance the days that you will be gone. Think of your withdrawal days as a vacation. We all know how well we work just before vacation. We become more efficient, and that work that has been piling up either isn't needed any more and is thrown in the garbage or you get it done.

Second, find the number two person on your crew and put him in charge for the days you will be gone. There is a real danger here. It is the danger we fear the most. While you are gone your crew will set production records, and when you get back they will be so tired they will only work for you at three-quarter speed.

Now that we have scheduled our withdrawal, what do we do? We go out to the planting site and stand by proudly as they plant your super trees. The first thing you will notice is that your trees don't look as big in the brush as they did on the packing line. You will mumble to yourself that those borderline trees that were packed to reach your quota really shouldn't be here. Those big luscious root systems are not much good when they cannot be planted properly. This is quite humbling, but it is necessary.

Talk over with the local forester the problems you both have and discuss solutions. Now you have a feel for the forester's problems, and you can let the forester know some of the nursery's. Discuss planting techniques that you feel need correcting. You will get better with this as you visit more sites. Each forester and crew has strong points and weak areas. They are usually not the same. Pass on information you have gathered from your previous visits.

The main thing is to show an interest. Look at the trees as they are planted and again a month or two later. Your return visit to the planting site will probably be a first for the forester. If the trees are in poor shape now, it will be the result of poor planting, storage, or growing and not the standard reason of drought. The forester is more likely to remember a recent frost now than in a year's time. Between the two of you the problem may be identified and hopefully corrected the following year.

Now I would like to answer those complaints I told you about earlier. Someone from the nursery went to the planting sites within a week of the call or on a regularly scheduled visit.

Thirty percent of the root systems were not acceptable on one lot out of five. It was also a small lot that was associated with poor seed.

Some of the trees were brown and were the result of a van freezing at the nursery. Also I discovered a root system problem in the field that related to poor quality control at the nursery.

Some of the trees did break bud, but not from poor storage. The lot number with the problem was lifted late.

The root systems were too long and needed better pruning.

We try to explain that falldown in the nursery is similar to field survival.

Some of the plugs were bare-root, but after they were growing for a year the survival was good. We did find that the inspector was paying the contractor for planting trees they were throwing away. Also the crew was stealing and reselling 1000-3000 trees a day.

The trees did die because of a grass killer that works well with bare-root but kills plug seedlings.

Finally, we get to "Those Wimpy Plugs". This forester doesn't like me or my trees, and I don't like him very much either. Maybe someone else could grow him a better tree, anyway.

BUSINESS MEETING

During the past number of years, there have been discussions about joining the Intermountain Nurserymen's Association and the Western Nursery Council into one group to be called the Western Nursery Association.

A motion was made and seconded that the Intermountain Nurserymen's Association be in favor of amalgamating with the Western Nursery Council. Motion carried.

The Western Nursery Council is to vote at its 1982 meeting to decide if it is in favor of amalgamating. If this passes, the new association will begin in 1983.

The combined meeting of the Western Nursery Council and the Intermountain Nurserymen's Association will be held in Medford, Oregon, August 10-12, 1982. The 1983 meeting is booked for Las Vegas, Nevada.

ATTENDEES AT THE INTERMOUNTAIN NURSERYMEN'S ASSOCIATION MEETING

AUGUST 11, 12, & 13, 1981

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